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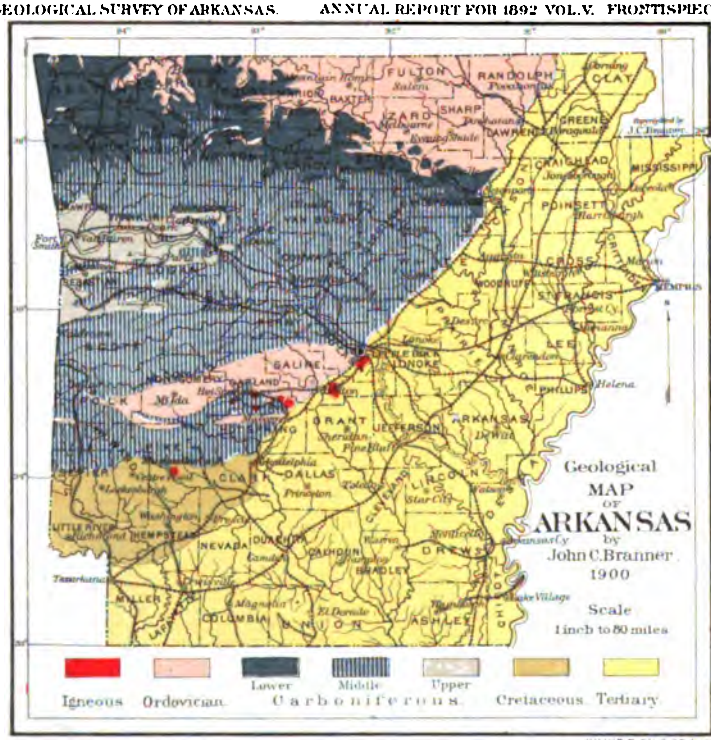

JULIUS BIEN & CO. N.Y.

ANNUAL REPORT

OF THE

GEOLOGICAL SURVEY

OF

ARKANSAS

FOR 1892

VOLUME V.

THE ZINC AND LEAD REGION

OF NORTH ARKANSAS

BY

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State Geologist.

LITTLE ROCK
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STANFORD UNIVERSITY, CALIFORNIA,
November 17, 1900.

To His Excellency,
Hon. Dan W. Jones,
Governor of Arkansas.

Sir:

At the expiration of my term of office as State Geologist of Arkansas (March 16, 1893) several volumes of my report remained unfinished. An appropriation made by the Legislature of 1899 for printing some of the unpublished volumes has made it possible to issue Volume V of the annual report for the year 1892. That volume I have the honor to submit herewith.

Your obedient servant,

JOHN C. BRANNER.

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PREFACE.

The work of the State Geological Survey upon the zinc and lead region of North Arkansas was begun in 1889. At that time next to nothing was known of the geology of the northern part of the State. All the problems of the rocks, their ages, character, distribution, structure, and history, to say nothing of the problems of the ores, were practically untouched, and all had to be worked out. There was then so much geologic work to be done in the State that the modest appropriation at the disposal of the State Geologist made it impossible to push the report upon the zinc region to immediate completion. The work was kept constantly in hand, however, and pushed as rapidly as circumstances would permit. Unfortunately the Survey was stopped when the study of the zinc and lead region was scarcely more than half completed. Much of the work done on other subjects and in adjacent regions has been available and helpful in solving the problems of the zinc and lead region itself, so that the delay has not been an unmixed evil.

When the report on zinc and lead was originally planned, it was intended that it should include the geology of the regions of the Kellogg mines and other zinc and lead mines of the southwestern portion of the State, but the suspension of the Survey made it impossible to embrace those districts, and the report has, of necessity, been confined to the territory no rth of the Boston Mountains.

At its session of 1899, the Legislature made an appropriation for the purpose of printing some of the unpub-

lished volumes of the Survey's reports. The amount appropriated was barely enough to print one of the five volumes. At that time the zinc report was furthest from being in condition for publication, but at the earnest request of Honorable A. C. Hull, Secretary of State, I undertook to get the manuscript of this volume ready for the printer. The field-work within the area treated was hastily finished at private expense in July, 1900, and since then the report has been prepared amidst many other pressing duties. This explanation is offered as a sort of apology for the defects of the volume.

The stratigraphy of the Ordovician rocks of the zinc region was one of the tasks left almost untouched when the work of the Geological Survey was suspended, and a lack of a thorough knowledge of this subject is now seriously felt in dealing with certain problems of the geology of the zinc regions. The paleontological paper forming Chapter VII, by Dr. Henry S. Williams, of Yale University, is the best and most comprehensive discussion written on the subject and is an important contribution to our knowledge of the age and classification of the rocks of North Arkansas.

The lead and zinc ores of North Arkansas are found for the most part in rocks of Ordovician or Lower Silurian age. The area of these rocks has not been thoroughly explored for zinc and lead and it is therefore impossible to say what portions of the Ordovician region might be omitted from the zinc and lead region of North Arkansas. This entire Ordovician area of the State is shown upon the geological map accompanying this report—not that it is meant that this area is all ore bearing, but that it is all worthy of attention in this connection.

The maps that form part of the report are correct in the main, but the scale is necessarily too small to show much detail. The maps of the atlas can, if it is desired, be

cut out and pasted together so as to show at a glance the geology of the entire zinc region from Walnut Ridge to the Indian Territory line. It is especially to be regretted that it has not been possible to make large-scale maps of certain typical areas, to represent upon them the details of structure, and to indicate the locations of those structural features that would enable the miner to find the principal ore bodies. It was intended to make such maps had the work of the Survey been continued, and it was partly to allow time for getting the data for such maps that the report was not sooner completed.

It is sometimes asked how many square miles of North Arkansas contain zinc. It is impossible to answer this question, for we have no data upon which to base any rational estimate.

Owing to the lack of time and means no attempt is made to discuss the lead ores and lead mines separate from those of zinc. Most of the lead mines and properties that were visited are mentioned in Chapter IV along with the zinc deposits.

The present volume was originally intended to form part of the annual report for the year 1892, and for the sake of uniformity it is so issued. The reader should bear in mind, however, that the report includes many facts gathered in the field as late as the summer of 1900.

Everywhere in the region the members of the Survey have been treated with the greatest courtesy and hospitality. Every one has been ready to give his time and service in order to help on the work. It is impossible to mention personally all these kind friends. Acknowledgments are especially due Professor A. H. Purdue, of the State University at Fayetteville, who has generously contributed his time and services in helping to gather information upon many of the zinc mines that could not otherwise have been visited; he has also kindly furnished (with proper permis-

sion) notes upon other properties that he has examined privately. And finally he has contributed his time and energies to the tedious and thankless task of seeing the report through the press.

Honorable A. C. Hull, Secretary of State, has also done everything in his power to facilitate the work and to get the report printed, and, as suggested above, it is to him, more than to any other one person, that its publication is to be credited.

JOHN C. BRANNER.

THE ZINC AND LEAD REGION

OF

NORTH ARKANSAS

BY JOHN C. BRANNER, State Geologist.

CHAPTER I.

THE PHYSIOGRAPHY OF NORTH ARKANSAS.

Sketch of the general topography.—The topographic relief of the State of Arkansas is about evenly divided from northeast to southwest into two different regions. The main line of the St. Louis, Iron Mountain and Southern Railway follows approximately the line of division. To the east and south of this the land is of low relief, very few of the highest hills being little more than five hundred feet above tide level, while much of the land, especially that lying near the largest streams (Mississippi, Arkansas, lower White River, Red River, and the Ouachita), is so low that it is flooded during high water in these streams.

To the north and west of the division line the relief is bold and more or less mountainous. This elevated region is cut in two by the valley of the Arkansas. To the south of that valley the mountains and hills are, for the most part, long east-west ridges extending from the lowlands on the east to the Indian Territory line on the west. In several cases these mountains have an elevation of more than two thousand feet above tide.

North of the Arkansas River and west of the St. Louis, Iron Mountain and Southern Railway the relief is high and rugged, but of a type entirely different from that south of the river. The region is an elevated plateau or set of plateaus rather than a mountain. The rocks lie in horizontal beds and are trenched by steep-sided gorges. This region is known in the State as the Boston Mountains; outside of the State it is generally spoken of as the Ozark Mountains—a name but little known in Arkansas as applied to any particular mountain or mountain system. The highest points in the Boston Mountains are between 2,000 and 3,000 feet above tide level. Plate I, made from a portion of the relief map of the State of Arkansas, gives a bird's-eye view of the Arkansas valley and of the Boston Mountain region.

The Ozark plateau.—The region here included under the name of the Ozark plateau embraces nearly all of that part of the Ozark Mountain region within the State of Arkansas. It includes almost the entire region between the Arkansas River and the Missouri line, and between the St. Louis, Iron Mountain and Southern Railway and the Indian Territory line. There should be excepted from this only portions of Pope, Conway, Faulkner and White counties, which, both geologically and geographically, belong with the mountainous and hilly regions south of the Arkansas.

The Ozark region in Arkansas is made up of three plateaus that rise like ragged edged steps one above the other, each with a few outliers standing out upon the next step below. The lowest one of these plateaus is in Ordovician rocks, is deeply eroded, and consequently presents an exceedingly rough topography. This area forms a rough triangle whose apex is near Newport, Jackson County, and whose base is on the Missouri-Arkansas line from Berryville to the east end of Randolph County.

A bird's-eye view of the topography of North Arkansas, looking eastward. From Branner's relief map of Arkansas.

Looking southwest from the top of the mountain east of Denton's Ferry on White River.

The next higher plateau or step is formed of Lower Carboniferous rocks, and lies between the triangle above indicated and the north-facing escarpment of the Boston Mountains. On this Lower Carboniferous limestone and chert (flint) plateau stands the Boston Mountains. To the south, these mountains for the most part break down gradually and merge into the hills and ridges along the north side of the Arkansas River.

As seen from the north it has a totally different aspect. A person standing on the high hills almost anywhere along the Missouri-Arkansas line and looking southward sees a flat-topped, wall-like mountain on the horizon. This mountain has many different names between its eastern end southeast of Batesville and its western end where it passes into the Indian Territory southwest of Fayetteville, but the range, as a whole, is known as the Boston Mountains.

From a point between Green Forest and Berryville, Carroll County, the topography of the Boston Mountains toward the east is in strong contrast with that toward the west. In the latter portion the high mountains break down gradually or merge by shorter steps and with more abundant but smaller outliers into the Lower Carboniferous plain along its northern base, while to the east the topographic contrast is stronger and the flat-topped mountains rise with abrupt escarpments from the lower plain, here nearly straight, and there cut into long finger-like ridges pointing northward, with steep sides and flat tops, or they are eroded into lofty isolated outliers.

Through that part of the mountains locally known as the Blue Mountains and lying between a point 12 miles east of Marshall and the town of Batesville, Independence County, the north-facing escarpment is almost unbroken by ravines. From 12 miles east of Marshall to Green Forest, Carroll County, gorges many miles in length cut

back into the high mountain plateau, leaving long, steep-sided ridges projecting upon the Lower Carboniferous plateau.

The narrow canyons that thus dissect the high mountain plateau on Buffalo Fork and Richland Creeks are from fifteen to twenty-five miles long and in some cases they are as much as 1,200 to 1,500 feet deep (Point Peter, the prominent headland near Jasper, is 1,030 feet above Richland Creek.—J. F. Newsom, aneroid barometer). Plate III shows the characteristic topography about the upper portions of Little Buffalo, Big Buffalo, Cow Creek, Richland Creek, Calf Creek, etc.

East of Wiley's Cove there are very few outliers along the north face of the mountain; west of Wiley's Cove the ridges are separated here and there from the mountain mass and outliers are left standing out isolated upon the plain. Some of these are: Cow Mountain, Panther Mountain and Roper Mountain, west of Mountain View; and the cluster, seven miles south of Bellefonte, whose peaks are known as Pilot, Boat, Pinnacle, Sulphur and Fodder Stack Mountains. In the region about Harrison the great wall-like, flat-topped Gaither Mountain dominates the landscape, while between Harrison and Carrollton, Pilot Knob and Round Mountain are its striking outliers.

It has already been said that there is a marked change in the topographic relief along the north face of the Boston Mountains west of Green Forest, Carroll County. From this point westward the relief contrast between the higher mountains and the Lower Carboniferous plateau is not so marked, the mountain's north face is not so bold and precipitous, and outliers are more numerous but less prominent, and the Lower Carboniferous shelf is much broader than it is toward the east end of the mountains. From Gaither Mountain and Pine Mountain near Green Forest the Boston Mountain range extends past and just south

Looking S. 40° E. up Little Buffalo Valley, on the north face of the Boston Mountains. The Coal Measures form the summits and the Lower Carboniferous the lower slopes.

of Huntsville, Madison County, south of Fayetteville, and passes into Indian Territory at Evansville, Washington County. Between Eureka Springs and Huntsville the outliers are not so large as those south of Harrison, but they rise above a somewhat flatter plain, and this gives them a greater prominence than their size would otherwise entitle them to. These outliers are: Grindstone, Pond and Swain Mountains south of Eureka Springs, and Means, Aunt Katy and Keefer Mountains near Hindsville.

Where the St. Louis and San Francisco Railway crosses the Ozark plateau near the Missouri-Arkansas line there is a group of these small outliers rising above the general level of the country. This group includes Pea Ridge—the historic site of a battle during the Civil War—Blansett, Gentry, Radcliff, Pond, Poor, Rich, Glasscock and Little Sugar Mountains, and the Devil's Eyebrow. These peaks are all in the vicinity of Garfield station. Fayetteville stands at the west base of one of these outliers, East Mountain, while in the immediate vicinity are Pierce, Millsap, Kessler, Washington, White Oak, Washburn, Brooks, Baxter and McCullom's Mountains.

Similar peaks but less prominent ones are scattered along the north face of the Boston Mountains from Fayetteville to Evansville. One of these, Cane Hill, has an elevation of 1,600 feet above tide level. The outliers here mentioned are all comparatively near the north-facing escarpment of the Boston Mountains, and are remnants of the Coal Measures beds of those mountains left by denudation.

Beneath the sediments of the Coal Measures, rocks of Lower Carboniferous age form a shelf-like plateau that extends northward along the north face of the Boston Mountains. This lower shelf is also cut into by the streams so that it presents a more or less ragged northern edge with finger-like ridges between the larger streams, sometimes

broken at the ends into isolated outliers. Many of the hills north of Cushman, Independence County, are of this nature, although those hills do not stand out prominently as typical outliers. Pilot Knob, about eight miles northwest of Melbourne, is one of these outliers capped with Lower Carboniferous rocks. Of similar origin and character are Matney's Knob and the flat-topped mountains between it and the mouth of Buffalo Fork; the highest hills south of and within four miles of Buffalo City; Hall Mountain, Mount Ephraim and Bald Jesse near Yellville; the marble-capped peaks of Lee's Mountain west of Flippin; the isolated hills north of Berryville and several others in the valleys of King's River and of White River, north and west of Eureka Springs. These outlying peaks stand upon a floor of Ordovician rocks. From the White River, where it crosses the Missouri line north of Eureka Springs eastward to Black River in Randolph County, the rocks along the northern edge of the State are all horizontal beds of Ordovician age, excepting only the divides between Indian Creek and Bear Creek, in the northern part of Carroll County. These Ordovician rocks are, in this State, the floor or lowest beds upon which the higher rocks rise. Along this northern border these old beds have been everywhere cut into by the streams, while here and there isolated peaks have been left by the long denudation to which the region has been subjected. The country about Mountain Home, for instance, is for the most part a great plateau scored on the edges by the gorges of streams flowing into White River and its large tributaries. The hills rising above this plateau were once capped by Lower Carboniferous rocks, but these caps have now disappeared. Of such origin are Sugar Loaf Mountain, two miles north of Lead Hill; many of the isolated peaks along White River; those north of Flippin and along the lower part of Crooked Creek; the isolated peaks north of

Characteristic bluffs of Ordovician rocks on White River, near Eureka Springs, Arkansas.

The residuary hills on the plateau near and north of Mountain Home.

Mountain Home; Perry's Knob, Naked Joe, Turkey Knob, Twin Knobs and Devil's Knob—all along the lower White River before it emerges from the hilly country below Batesville.

There is a remarkable topographic break cutting across the eastern end of the area shown on the maps accompanying this report. It appears on the maps like a line of low hills skirting the western edge of the Black River bottoms. This line of hills is at or near a former shore-line of the Gulf of Mexico when its waters covered all the lower Mississippi basin as far north as the mouth of the Ohio River.

The drainage.—The White River and its tributaries drain nearly all the lead and zinc region of north Arkansas. The tributaries that flow through Arkansas territory nearly all head in the Boston Mountains and flow northward into the main stream. Those that head near the water-shed of the Boston Mountains flow through deep and steep-sided gorges in their upper portions, then emerge upon the great plateau of older rocks lying north of the mountain range. Over this plateau the streams have winding courses, but they still flow through narrow valleys and their waters wash the bases of vertical cliffs of hard rock first on one side and then on the other. Most of the valleys are so narrow that they have little or no bottom land. The winding river courses upon this great Ozark plateau look so much like the winding of sluggish streams in a low, flat region, like that of the Arkansas between Pine Bluff and the Mississippi River, that Professor W. M. Davis, of Harvard University, has attributed their form to the rejuvination and cutting down of such streams.* The idea is that this plateau once stood at a much lower level, that its streams were sluggish and winding very like those of the

* Science, April 28, 1893, XXI, 226-227.

lower Mississippi, and that when the region was raised to its present elevation the drainage was so quickened that the streams deepened their channels, but left them still crooked. The slopes or sides of the channels, however, lend no support to this theory. If Crooked Creek and White River had had such a history they might be expected to flow through narrow gorges having both sides steep. Those streams, however, so far at least as my observations go, never have steep bluffs on both sides, but they have gradual slopes on the inside and steep perpendicular bluffs on the outside of their curves. (See plate VI.) Another of their characteristics is that water-worn material is generally strewn along down the slopes facing the concave sides of the curves. This material is not spread out evenly, but usually occurs in patches that suggest obscured terraces. Now and then these gravel deposits occur at the same or nearly the same elevation, but I have been unable to find any systematic arrangement of them. To make a long story short, this water-worn material has been left behind by these same streams, as they have cut their channels down through the rocks. The distribution of the gravels and the forms of the sides of these channels show that the streams have been getting more and more crooked.

The beautiful springs of clear, cold water that are found all through north Arkansas form one of the attractive features of the region. A list of these springs is quite impossible. Some of the waters are regarded as having medicinal properties. Analyses have been made of many of the springs of the regions; these are given in the Geological Survey's report upon the mineral waters of the State.*

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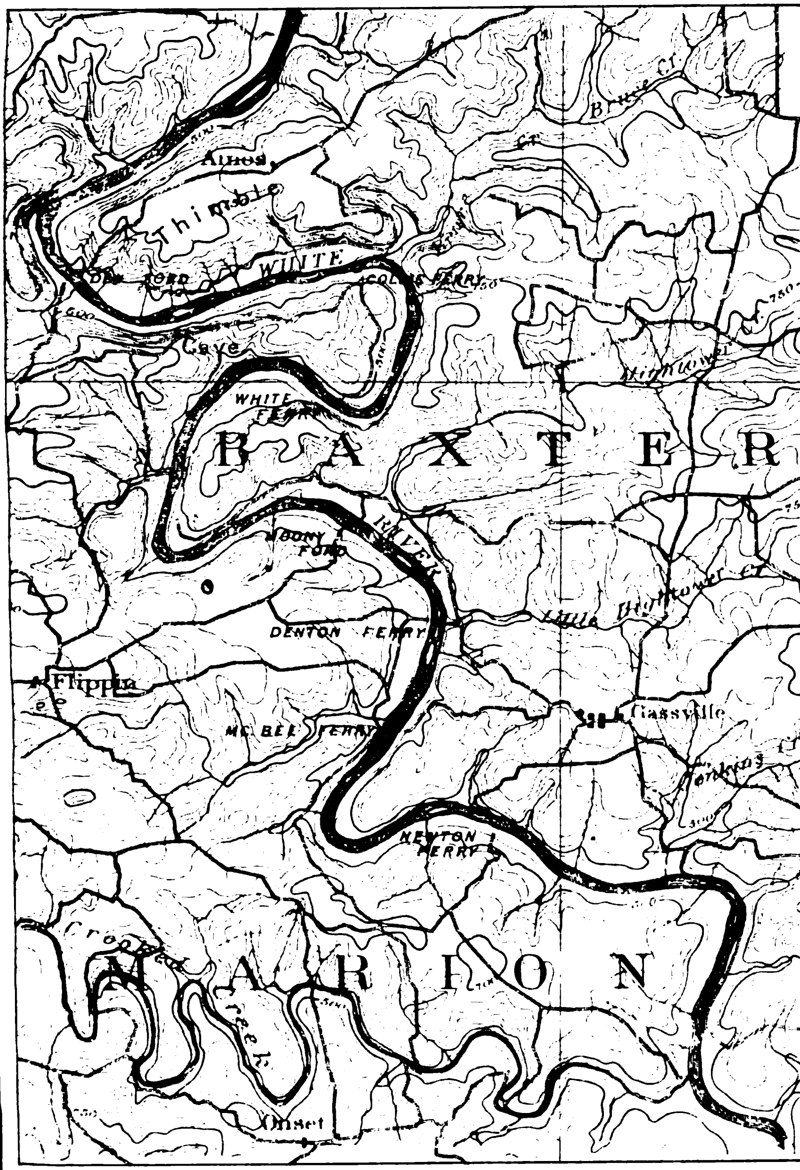
* The mineral waters of Arkansas. By J. C. Branner. Little Rock, 1892.



TOPOGRAPHY ALONG PORTIONS OF WHITE RIVER AND CROOKED CREEK SHOWING THE STEEP SLOPES ON THE OUTER AND THE GENTLE SLOPES ON THE INNER CURVES.

Scale: 1 inch = 2 Miles

0 ¼ ½ ¾ 1 2 3 4 5 MILES

0 1 2 3 4 5 6 7 8 KILOMETRES

Topog. from U. S. Geol. Sur. Topog. Sheets.

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CHAPTER II.

THE ZINC ORES; THEIR CHARACTER, ORIGIN AND DISTRIBUTION.

The zinc ores of North Arkansas in the order of their importance are *sphalerite* (zinc sulphide), popularly called "jack," "rosin jack," etc., *smithsonite* (zinc carbonate), and *calamine* (zinc silicate). In addition to these, there are several minerals of zinc that are more or less abundant, but they do not occur in sufficient quantities to entitle them to be looked upon as ores—at least not at present.

Sphalerite.—Sphalerite theoretically contains 67 per cent. of metallic zinc, though as a matter of fact such a high percentage of zinc is never found in sphalerite. The zinc ore of this region, however, contains a remarkably high percentage of zinc, as will be seen from the following determinations:

Determination of metallic zinc in North Arkansas sphalerite.

Mines.	Metallic Zinc.
Bear Hill	66.46 per cent.
Hiawatha	66.27 per cent.
Panther Creek	65.88 per cent.
Yankee Boy	65.88 per cent.
St. Joe	65.78 per cent.
Prince Frederic	65.68 per cent.
Governor Eagle	64.48 per cent.

These samples were taken at random, and though they do not represent the zinc contents of car-load lots, they do represent the composition of the clean zinc blende from the mines named, and these mines are not different in this respect from hundreds of others not included in this list.

The composition of the clean crystals of sphalerite is a matter of importance. Zinc ores are now bought upon analysis, and, however clean car-load lots of ore may be the percentage of metallic zinc in car-load lots can never be higher than the percentage found by the analysis of an average piece of clean zinc blende. At present (October, 1900) a given price per ton is paid for 60 per cent. zinc blende. If it assays less than 60 per cent. metallic zinc, one dollar is deducted for each per cent. less than 60, and if it assays more than 60 per cent., one dollar for each additional per cent. is added to the price paid. The analyses of Arkansas sphalerite show that if the ore be clean it will sell at from four to six and a quarter dollars a ton more than the average.

Sphalerite always contains impurities, some of which have an important bearing upon the market value of the ore. For instance, deductions are made for lead and iron found in the zinc blende if the amount exceeds a certain percentage. At a few places in this region lead is associated with the zinc blende, but for the most part there is no lead with the zinc.

The following complete analyses show the iron and other constituents of average samples of zinc blende.

Analyses of sphalerite from North Arkansas showing iron contents.

MINES	Sulphur S	Zinc Zn	Silica SiO_2	Iron Fe_2O_3	Magnesia MgO
Yankee Boy	65.88	81.77	0.10	0.62	0.14
Hiawatha	66 27	32.58	0.21	0.39	trace
Governor Eagle	64.48	32.16	1.88	0.26	0.00
Panther Creek	65 88	32.80	0.00	0.49	trace
Prince Frederic	65.68	33.33	0 09	0.15	0.03
Hunt, M. & B	58.68	20 36	0 10	0.20	0.10
St. Joe	65 78	32.92	0.11	0 15	0.08
Bear Hill	66 46	32.30	0.25	0.15	0.20

Other determinations of the iron contents of the sphalerite have been made. The largest amount of iron found in any one was 0.67 per cent.

One often hears it remarked that the ores of one mine are unlike those of another. This is quite true, but it is not a matter of any special significance. The ores do vary somewhat in chemical composition, but these variations are not greater than one may frequently find between two specimens taken from the same opening.

Smithsonite.—The theoretical composition of smithsonite is as follows: Zinc protoxide, 64.8; carbon dioxide, 35.2 per cent. The zinc contents are equivalent to 52.0 per cent. of metallic zinc. Here again the analyses always find impurities, so that the percentage of metallic zinc in smithsonite is always less than 52.0 per cent. The analyses made of the Arkansas smithsonite show it to be of excellent quality. The analyses given below, however, having been made from hand specimens for the purpose of ascertaining the composition of certain types, must not be accepted as analyses of car-load lots. Owing to the large amount of foreign material held mechanically in all large lumps of smithsonite, analyses of car-load lots would necessarily run lower in zinc than do these particular specimens.

Analyses of smithsonite.

	Morning Star	Legal Tender
Zinc oxide	64.31	62.20
Carbon dioxide, CO_2	34.93	33.86
Water, H_2O	0.58	2.30
Silicia, SiO_2	0.10	0.02
Magnesia, MgO	0.03	0.18
Lime, CaO	0.90	1.25
Iron and Alumina, Fe_2O_3 & Al_2O_3	0.12	0.21
Cadmium, Cd	trace	trace

The zinc oxide found in the specimen from the Morning Star mine, given above, is equivalent to 51.60 per cent.

of metallic zinc; that from the Legal Tender is equivalent to 44.97 per cent. of metallic zinc.

The yellow mineral known in the mines as "turkey fat" is smithsonite colored with a little cadmium sulphide. The composition of a typical example is shown by the following analyses:

Analyses of "turkey fat," a yellow variety of smithsonite.

	No. I	No. II
Zinc oxide, ZnO	63.84	61.20
Carbon dioxide, CO_2	34 60	......
Water, H_2O	1.09	......
Silicia, SiO_2	0.25	......
Magnesia, MgO	0.07	.....
Lime, CaO	0.70	......
Cadmium sulphide, CdS	0.90	0.82
Iron, Fe_2O_3 and Alumina, Al_2O_3	0.42	trace

The zinc oxide in No. I is equivalent to 51.22 per cent. of metallic zinc; that in No. II is equivalent to 49.11 per cent. of metallic zinc.

Smithsonite sometimes occurs as a red, yellow or brown "sand." In such cases the so-called sand grains are small individual crystals of smithsonite. Sometimes these particles are loosely held together, at others they are compactly cemented.

A white, earthy form of smithsonite occasionally found in the zinc mines was formerly supposed to be a new mineral and was called "brannerite" by Mr. W. A. Chapman, of Smithville, Ark. Typical examples of this mineral from Coon Hollow, Boone County, were analyzed. The results are given below.

Analyses of the mineral called "brannerite."

	No. I	No. II
Zinc, Zn	63.87	64.41
Carbon dioxide, CO_2	32.82	32.82
Silicia, SiO_2	0.22	0.24
Iron, Fe	0.32	0.35
Copper, Cu	0.79	0.78
Water, H_2O	0.16	0.12
Combined water, H_2O	2.18	2.18
	100.36	100.90

These analyses seem to show that this supposed new mineral is smithsonite mixed with some other matter. (See chapter VI on minerals.)

As is pointed out elsewhere in this volume smithsonite is formed by the alteration of sphalerite. The early zinc mines of Lawrence and Sharp Counties, Arkansas, were mines of smithsonite, and the ore was found in the surface clays and soils along and near the outcrops of deposits of zinc blende.

Although there is hardly a zinc prospect in North Arkansas that has not yielded some smithsonite, there is but little search nowadays for smithsonite alone. I feel reasonably confident, however, that when the search for our zinc ores has been properly systematized, large bodies of zinc carbonate will be discovered. These are most likely to be in regions of deep rock decay. And it should not be forgotten that some of the most important and best paying zinc mines in the world have been mines of smithsonite. It generally occurs not in hard rock like sphalerite, but in clays or soil where less expensive labor is required to extract it. And there is always a good demand in the market for the carbonate ores.

Calamine.—Calamine is a silicate of zinc, and theoretically containing 67.5 per cent. of zinc oxide, which is equivalent to 54.16 per cent. of metallic zinc.

Like smithsonite, calamine is an alteration product derived from sphalerite. It is much less abundant in Arkansas than either sphalerite or smithsonite. The most abundant deposits now known are in the Sugar Orchard district. The Almy mine is probably the most remarkable producer of calamine now known in the State. There are other prospects in that vicinity that upon further development will likewise yield large quantities of calamine.

On account of lack of time and funds no quantitative analyses have been made of the Arkansas calamine.

Tallow clay.—What is commonly known in the zinc mines as "tallow clay" or "buck fat" is not a definite mineral, but a mixture, probably of common clay and the mineral calamine. At present this material is not looked upon as an ore of zinc, simply because no satisfactory process of smelting it has as yet been devised.

Tallow clay has a peculiar "feel," by which it is commonly known. It occurs in pockets and seams in the rocks in nearly all of the zinc mines of North Arkansas. In some of the mines it is found in great abundance. The following analyses show the composition of typical Arkansas tallow clays.

Analyses of Arkansas tallow clays.

MINES	Zinc Oxide ZnO	Silica SiO_2	Alumina Al_2O_3	Ferric Oxide Fe_2O_3	Ferrous Oxide FeO	Lime CaO	Magnesia MgO	Potash K_2O	Soda Na_2O	Water H_2O
Buffalo	14.10	51.03	16 98	5.98	0.69	1.16	1.34	0 45	0.00	8.88
Big Elephant	13.97	45.10	16 52	5.65	3.16	2 70	1.58	1.15	0.62	10.89
Post Boy	34.79	40.91	9.38	2.25	0 52	3.42	0 48		0.42	9.02
Coon Hollow	37.76	37.04	8.85	1.68	0.42	3.58	0.77	0.27	0.56	8.76
Kansas	35.88	41.67	8 47	2.35	0.34	1.36	0.51	0 57	0.07	8.28
Markle	37.54	36.65	10.05	2 86	0.53	2.20	1 62	0.35	0 40	8.92

It will be noticed that in proportion to their present importance there are more analyses given of the tallow clays than of the zinc blende. But enough analyses have been made of the North Arkansas sphalerite to show that it is uniformly of excellent quality and that is all that is essential. In the case of the tallow clays, they are comparatively unknown, and if they are ever to become available their composition must first be determined. There are several other forms of zinc found in the zinc regions, but they occur too sparingly to have any importance as ores of zinc; these are hydrozincite, zincite, aurichalcite and goslarite. They will be found mentioned in the list of minerals in this report, chapter VI. Besides these there are probably several other forms of zinc that have not as yet been identified in this region.

THE ORIGIN OF THE ZINC ORES.

If in treating of the origin and concentration of the ores we seem to indulge in hypotheses, they are, so far as we can determine, founded upon facts collected in the mines and in the field. The general theory of the underground movement of waters has been used before our University classes in geology for the past fifteen years. The details of the theory of the accumulation of the Arkansas ores along synclines and other waterways were first suggested by field observations made in this region in 1889, and the whole theory has been much strengthened by subsequent work.

There is little, if anything, new in the hypothesis, however. Mr. Arthur Winslow, formerly State Geologist of Missouri and our best authority on zinc ores, puts forward practically the same theory in explanation of the zinc deposits of Missouri.*

It may be, however, that other writers have not gone into the details of synclinal accumulations and water way breccias as they are here treated. These are small matters, to be sure, but it is hoped that they may prove useful to the zinc miners of North Arkansas.

CLASSIFICATION OF THE ORE DEPOSITS.

The sulphide ores considered with reference to the beds in which they occur are divisible into two general classes: I, those contemporaneous with the enclosing beds; II, those in which the ores are of later origin than

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* Mr. Winslow briefly states his theory in the *Journal of Geology*, 1894, vol. I, p. 617. "If we accept the broader idea of lateral secretion which does not demand that a mineral shall be derived from the very rock to which it is attached, but recognizes abundant flow along crevices and through porous strata, and a consequent free transfer of solutions from place to place, all the phenomena find an equally ready explanation."

See also a paper by Professor W. P. Blake in the Transactions of the American Institute of Mining Engineers, 1893, vol. XXII, pp. 621-646.

the rocks with which they are associated. But the gangue rocks of the veins and the gangue rocks of certain other breccias originate somewhat differently; we may therefore consider that genetically there are three kinds of sulphide deposits:

I. The bedded deposits which are contemporaneous with the rocks in which they occur.

II. The veins and other fracture deposits in which the ores are of later age than the accompanying beds.

III. The breccia deposits not formed on fractures, but likewise of later age than the accompanying beds.

IV. In addition to the sulphide ores there are carbonate and silicate ores derived by alteration from the sulphides and forming, genetically, a fourth class.

I.—THE BEDDED DEPOSITS.

Their forms.—The bedded ores occur chiefly in cherts or in quartzitic rocks that contain more or less chert. In a few instances the bedded ores are in dolomites. These ores follow the bedded planes of the rocks to which they are confined. This is illustrated by a great many of the mines, among which are the Little Rock on the north side of Hall Mountain; Silver Hollow mines, on Big Buffalo; the McIntosh, Morning Star and White Eagle mines and many others described in chapter IV.

The ore-bearing beds vary greatly in the amount of zinc blende they contain; a bed may be very rich at one place and quite poor at another, but still in a given region covering two or three cadastral townships the bedded ores are confined to one particular stratum, or perhaps to two or three strata. Owing to local conditions a single ore-bearing bed frequently varies greatly in character, so that it may hardly be recognizable as the same rock even throughout a single mining claim.

Origin of the bedded deposits.—The bedded deposits of zinc have originated for the most part where we now

find them. The cherts are made of silica of organic origin, that is, they were deposited over the sea bottom as the siliceous skeletons of diatoms or other microscopic remains of plants or animals. The zinc came from the adjacent land areas of the period in which these beds were laid down. Upon entering the sea the zinc-bearing waters had their zinc contents precipitated in the form of sphalerite or zinc sulphide by the organic matter that contributed the silica of the chert beds. The zinc blende crystallized out while these siliceous sediments were yet soft and yielding. In time the sediments hardened and formed the firm, flinty rocks and pressed closely about the zinc blende crystals.*

The crystals of zinc blende, however, were not originally as large as we now find them in the disseminated ores, even where these crystals are no larger than a pin head. They were at first even microscopic, but, as Ostwald has pointed out,† there is a tendency in such cases for the small crystals to pass into solution and to recrystallize upon the larger ones which grow at the expense of the small ones. In the bedded deposits this took place before the enclosing sediments were hardened.

Still later these ore-bearing beds were buried beneath other sedimentary deposits. Most of the beds that originated in this way were formed during Ordovician times. Zinc-bearing beds were deposited in this manner again during Lower Carboniferous times, but apparently only on a small scale and locally in the Arkansas zinc fields.

Changes affecting bedded deposits.—The beds in which the zinc blende was deposited have undergone many

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* An interesting occurrence of both galena and sphalerite in soft sedimentary rocks is mentioned by Harris and Veatch in their late (1899?) report on the geology of Louisiana, pp. 225-226.

†Über die Vermeintliche Isomerie des roten und gelben Quecksilberoxyds und die Oberflächenspannung fester Körper. Von W. Ostwald. Zeitschrift f. Physikalische Chemie, Aug., 1900, XXXIV, 495-503.

changes. The marine sediments have been lifted out of the water and made into dry land; they have been subjected to so much pressure and twisting that they have been bent in some places and in others broken across and displaced. In some instances the beds have been broken into many large angular blocks that no longer fit together nicely, but so crowd each other as to tip this way and that with the edges broken and crushed against each other. Being lifted from beneath the sea the upper beds have been attacked by streams that have cut gullies deeper and deeper into them and wider and wider until some of them are hundreds of feet in depth, and a mile or more in width. From this briefly stated history it will be seen why it is that through so large a part of the zinc region of North Arkansas the ore beds are high in the hills. They have been left there by the erosion of streams that have cut their valleys down through the zinc beds into the underlying sediments.

It will be seen also why the same bed is at one place high in the hills and at another place beneath the floor of an adjacent valley. In the Rush Creek region the zinc beds of the Morning Star and the McIntosh mines are high on the hills at those mines but they are below the level of Buffalo River at the White Eagle mines. This is due to a gentle folding of the rocks of that district. The zinc-bearing bed of the White Eagle mine is below the level of Buffalo River, while on the east side of that stream the same ore-bed is twenty feet above the river. It is the same ore-

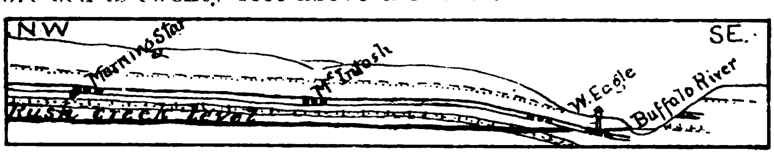


Fig. 1. Section along Rush Creek, showing the eastward depth of the zinc-bearing beds.

bed, but it is let down on the west by a fault. Many similar instances might be cited to show that the ore-bearing bed is subject to all the changes that are liable to affect any sedimentary bed of rocks.

II.—THE VEIN DEPOSITS.

Their forms.—The ore-bodies here spoken of as veins are fractures often of great size and length, cutting across the sedimentary rocks vertically or usually, though not always, at a high angle. These fractures sometimes leave the two walls of the broken beds closely pressed together; at other times a belt or zone from five feet to twenty feet or more in width is filled with angular or more or less crushed material. The beds on opposite sides of one of these fractures may be displaced either vertically, laterally, at some angle between the two, or perhaps not at all. In some of these fractures the walls or sides of the break are striated horizontally, showing that there has been a horizontal displacement of the two sides. Such marks are well shown on the sides of fractures at the Panther Creek mines, and at the Chimney Rock mines. (See plates XVII and XIX.) These fractures can be traced across the country at times for many miles.

The ores associated with these fractures are confined to the fractured zone and to its immediate walls. When the ore is found in the walls it seldom penetrates them to any considerable depth, but is confined to small fractures that seem to be parts of the great fissures.

The origin of the fissure ores.—The ores found in the veins or fissures are not different in appearance from those found in the beds, but they have had a very different history. The fractures in which these vein deposits occur may cut through rocks of any age. The vein deposits of Newton County are in Lower Carboniferous rocks, but they pass downward into the underlying Ordovician beds. In other places the fissures cut across Ordovician beds only. Some of these fissures contain ore, but many of them carry but little or none at all. The ores that fill them have been brought into their present position in solution. Inasmuch as almost the only zinc-bearing rocks in which the depos-

its are original are in the Ordovician sediments, it seems highly probable that these fissure deposits have been brought into their present position from the Ordovician bedded deposits. The direction of the movement of such solutions has been much discussed by geologists, and there have been great differences of opinion as to whether the mineral matter deposited by them is derived from rocks above, below, or at the sides of such deposits. But the waters that pass through the rocks of the earth's crust obey the laws of hydrostatics, that is, they move in any and every direction according to the shapes and positions of the channels through which they pass and the pressure that causes them to move through the rocks, so that the same particle of water is at one time moving downwards, at another time moving laterally and at another time moving upwards, according to the pressure behind it and the shape of its channel. The well-defined position of the original zinc deposits of North Arkansas and the present position of the later ores shows that the underground waters have moved in all these directions, for in some instances the fissure deposits are above, in other instances adjacent to, and in still others they are below the original beds. In the Big Buffalo district about Boxley the veins or ore-bearing fractured zones pass up through Lower Carboniferous rocks. The ores in these fractures have been brought up from the zinc-bearing beds of Ordovician age. Although these mineral-bearing solutions have passed upward geologically, that is from the lower and older to the upper and newer beds, it does not follow that they have always and only moved upward hypsometrically. There have been many changes of level during the geologic history of this region, and underground watercourses would be more readily affected by such movements than would the surface drainage. In the Rush Creek mines the ores are both adjacent to and below the horizon of the original beds.

III.—THE BRECCIAS.

Brecciation or the breaking up into angular fragments and the recementing of these fragments into compact beds occurs in all the kinds of rocks found in the zinc regions of North Arkansas—cherts, quartzites, dolomites, and even in sandstones and shales. When the shales are brecciated, however, the fragments generally crush together so that they do not preserve their brecciated appearance so plainly as do the harder rocks. Where the zinc-bearing waters have passed through these brecciated rocks, the cavities have been filled with zinc ore and with other minerals—usually dolomite spar or calcite.

The question of the origin of the breccias has been one of the most puzzling problems encountered in the zinc regions. The difficulty of determining the exact form and extent of the breccias is probably the chief obstacle to a

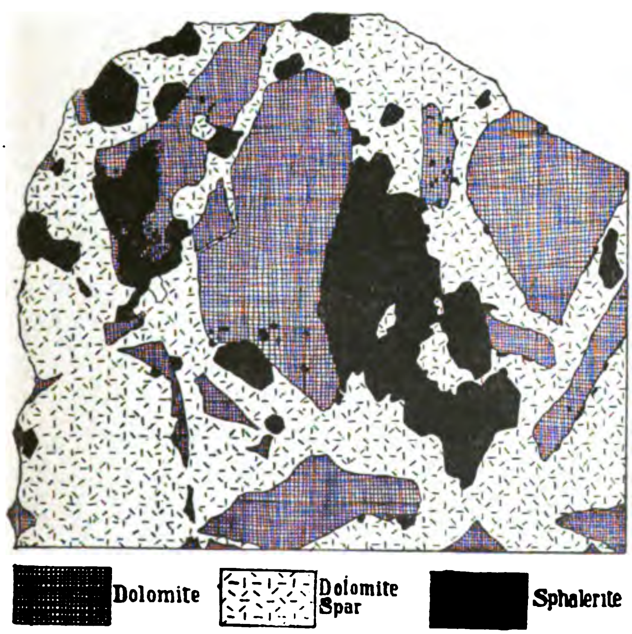


Fig 2. Breccia from the Democrat mine, showing angular fragments of dolomite cemented with sphalerite and dolomite star; natural size.

satisfactory explanation of them. Those breccias that occur along faults or fissure zones require no other explanation than that suggested by the faults and fissures themselves; the breaking across the bedding planes and the dis-

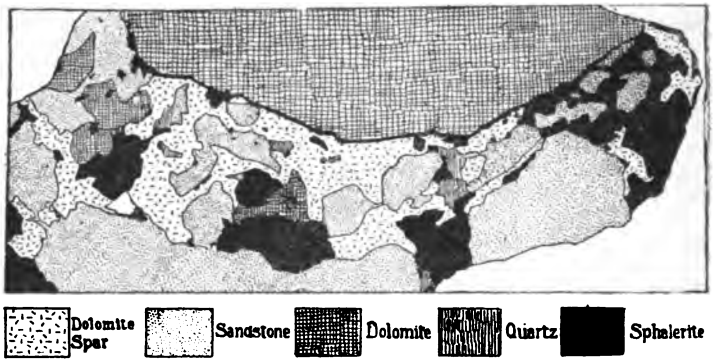


Fig. 8. Brecccia of dolomtte and sandstone cemented with spalerite, dolomite spar and quartz; half the natural size. From the Red Cloud mine on Buffalo River.

placement would naturally break off and catch much angular material between the two faces of the fractured beds. But in many instances the breccia is a distinct bed with the overlying and underlying beds apparently undisturbed. This suggests the possibility of an overthrust fault with the breccia on the plane of displacement. But if such faulting took place it is extremely doubtful whether such a breccia would be formed; the strata affected would be held down by the great weight of overlying rocks and the beds would tend to glide over each other without any great amount of fracturing; certainly such a movement would not satisfactorily explain a five foot bed of breccia between beds showing no signs of disturbance. It seems probable that the brecciation of a horizontal bed lying between two other undisturbed beds is apparent rather than real. It is noticeable that these brecciated beds sooner or later come to an end, sometimes abruptly, and that the rocks beyond are generally of the same kind as the brecciated material, though there are often mingled with it fragments that have apparently come from overlying beds.

The only theory for these formations that seems tenable is that most of the apparently irregular masses of breccia, that is, the breccias not upon faults and such like fractures, have been formed along ancient underground watercourses. These watercourses have been filled up partly by fragments of the wall rocks, some of which have been washed in from overlying beds, and partly by the cementing of these fragments by the deposition of dolomite spar, calcite and zinc blende. The exposures one gets of the breccias are sometimes across or at right angles to the comparatively narrow waterways and at other times parallel to them. When the section follows the breccia for a long way it has the appearance of being interbedded; when the section crosses the line of brecciation at a high angle the breccia appears to be purely local.

It will be seen from the method of their formation that the precise form and extent of the brecciated ore bodies cannot be predicted much in advance of exploration. Some of them are of great extent and contain large bodies of ore, while others are of small extent; some of them are very rich, and others, or other portions of the same masses, are poor or altogether barren.

The general conclusion to be drawn from the preceding discussion is that the North Arkansas ore bodies that occur in faults, fissures and breccias, are all deposited along old underground waterways. Many, perhaps most of these ancient watercourses, have long been closed. This feature of the breccias will be referred to again under the discussion of the relations of structure to ore bodies in this same chapter.

Comparative importance of the deposits.—The question will arise as to which of these kinds of deposits is likely to prove most valuable, the beds, the veins or the breccias not formed on faults. There is a strong prejudice among miners in favor of fissures or fissure veins. Wher-

ever this idea may have originated and however important it may be in other mining regions, it is without value for the miners of North Arkansas. A deposit in a fissure may be rich or it may be poor; the same thing is true of the brecciated deposits and of the bedded deposits. If a vein is rich at one place it does not warrant one in concluding that other veins will be rich, or that bedded deposits will be poor.

IV.—THE ALTERATION OF THE ZINC ORES.

Smithsonite (zinc carbonate).—In some of the zinc mines only smithsonite is found, in others only calamine, in others only sphalerite, while in still others one finds all sorts of mixtures of these several forms of zinc ore. Invariably, however, sphalerite is the form of the zinc found in those rocks that are quite unaffected by weathering or surface agencies. An interesting fact in this connection is that rocks once containing crystals of zinc blende are now sometimes open textured—full of the angular cavities left by the removal of the zinc blende in solution. The cavities thus produced are sometimes of microscopic size, sometimes an inch or more in diameter. Dr. J. P. Smith has kindly made casts of some of these cavities for me and he finds upon measuring their angles that they have been shaped by crystals of sphalerite. Such cavities, however, occur only in rocks that show other evidences of having been affected by surface waters and weathering agencies. The smithsonite or zinc carbonate is invariably found in greater or less abundance along the outcrops of the beds that contain sphalerite. Many of the openings for zinc yield only smithsonite on and near the outcrop of the zinc-bearing bed, while in proportion as the unweathered beds are penetrated the sphalerite takes the place of the smithsonite. With this fact every one acquainted with the zinc region is perfectly familiar. In some instances, however,

the carbonate ore is found at great depths. This occurs, however, only where the open texture or broken condition of the rocks permits the infiltration of surface waters. It is evident in all of these cases that the smithsonite is formed by the alteration of the zinc blende and its recrystallization in the form of a carbonate. The ore may in this process of alteration be moved a short distance but so far as our own observations have gone it is seldom or never moved more than a few inches. In many instances crystals of zinc blende are altered to smithsonite in place. Analyses of large lumps of smithsonite almost without exception show the presence of some sphalerite. This is because the alteration of the sphalerite to smithsonite has not been complete and some small bits of the sphalerite are completely enclosed by the smithsonite.

The color of the beautiful yellow variety of smithsonite popularly known as "turkey fat" is due to the presence of a small amount of cadmium which is derived originally from sphalerite crystals which often contain a small amount of cadmium. In the yellow smithsonite the cadmium sulphide is sometimes as high as 0.90 per cent., while the sphalerite almost invariably contains at least a trace of cadmium sulphide.

Calamine (zinc silicate).—The calamine like the smithsonite is formed from the zinc blende, but it is not of such common occurrence as the smithsonite. It is especially abundant in certain mines in the Sugar Orchard district where the siliceous rocks are much broken. At several places where calamine is found the zinc blende has been removed in solution from the compact chert gangue rock and cavities thus left have been filled with crystals of calamine. Like smithsonite, calamine is often found in loose lumps in surface clays, and wherever it has been found in hard rocks, the rocks bear unmistakable evidence of having been much altered by the action of surface

waters. It frequently happens that openings in which calamine is found show also cavities filled or lined with thin layers of clear quartz crystals. This quartz is sometimes mistaken by the inexperienced for calamine.

THE RELATIONS OF GEOLOGIC STRUCTURE TO EXISTING ORE BODIES.

The bedded ores.—It has already been pointed out that the ore bodies of Arkansas are partly contemporaneous with and partly newer than the rocks with which they are associated. The bedded deposits were laid down in horizontal sheets along with the cherts, quartzites, and dolomites through which they are now disseminated as ores. Whatever changes have affected these rocks have affected the ores which are a part of them. Where the beds are bent, the ore bodies are bent; where the rock beds are faulted, the ore bodies are similarly faulted; and where streams have cut down through the rock beds valleys of various depths and widths, they have cut the same valleys through the ores.

Some mention should be made of the fear the miner or prospector often has of blasting into the face of one of these bedded zinc deposits lest it "go blind" or pinch out a little farther in. The bedded ores of North Arkansas do vary more or less in the thickness of the ore-bearing portions of the bed and in the percentage of sphalerite in a given amount of gangue. But these bedded deposits are remarkably even in thickness and richness, and if they change for the worse in a short distance, they may be depended upon to recover their richness within an equally short distance. No sudden changes in the thickness or richness of the bedded ore bodies should excite alarm; it is only the gradual thinning out or impoverishment of the beds that should cause uneasiness. Of course a fault may and often does bring the ore bed up against a barren wall,

but beyond the fault the bed can be relocated—usually with little or no difficulty—and followed up.

But while the rock beds and the bedded ore deposits have retained the same general relations to each other, there have been going on since the beginning slight alterations that have ultimately had an important influence upon the rocks and upon the ores. These alterations have been produced by the action of waters aided by whatever acids and alkalis they may have found at hand from time to time. The surface waters penetrating the soils and rocks have obeyed the laws of hydrostatics, and have followed whatever channels these laws and the nature of the rocks permitted. Their movements have not been rapid, but for the most part very slow. In their passage through the rocks these waters have dissolved certain minerals and shortly afterwards deposited them again. Reference is not made here to surface phenomena, such as we have in the formation of smithsonite, calamine and stalactitic deposits, but rather to the solution and redeposition of such minerals as sphalerite and even of quartz itself.

It is not uncommon to find in the region under discussion, the rocks associated with the Ordovician zinc beds to have undergone changes that have turned thin-bedded sandstones or some other quartzose sediments into rocks made up of double beds of small quartz crystals so arranged that the upper layer has the crystals terminating downward, while the lower one has its crystals pointing upward. In several instances of the kind there are crystals of sphalerite mingled with the quartz. Examples of the kind are especially abundant at the openings on the Little Rock claim on the north side of Hall Mountain near Yellville, and in certain parts of the Morning Star mines on Rush Creek. At many places cavities in the rocks are now in the process of being filled with crystals of zinc blende, calcite, dolomite, and in some cases with crystals of quartz.

It is a fact then that sphalerite passes into solution and that it recrystallizes. From the fact that we have cavities filled with crystals of sphalerite that must have been deposited since the formation of the fractures it is also evident that the zinc passes (in solution) from one part of the rocks to another. And inasmuch as the waters passing through the rocks afford a vehicle for carrying this and other mineral constituents, we must attribute such removal and redeposition to these waters. On one occasion when visiting certain mines we collected a red powdery scale that had been deposited in a pipe used to run the drain water away from a zinc mine. This powder contained a good deal of sand, apparently bits of the rock caught and held mechanically in the coating of the drain pipe. Upon analysis of the whole it was found that it contained 25.98 per cent. of zinc in the form of an oxide. Qualitative tests showed that there were no carbonates, sulphides or sulphates present; that silica and alumina were high, and that there were present also some iron and copper.

The nature and origin of this deposit seems to give support to the theory that the zinc in the rocks is liable to and actually does undergo removal from one place to another by a process of solution and redeposition, though not necessarily at so rapid a rate as in the case cited. We may here inquire what the ultimate effect of such action upon the original ore beds would be. It must lead to local loss and gain—to local diffusion and concentration—to local impoverishment and enrichment of the ore-bearing rocks. The ores are moved very slowly through the rocks along the channels followed by the waters.

A word is in place in regard to what is meant by subterranean watercourses. It is not intended to refer to what is usually understood by underground streams, such as issue as springs or flow through caves, but rather

to the courses followed by what is more commonly known as seepage water. This movement of water goes on not only in the higher but also at lower levels, and the concentration of the ores here suggested would not require any large amount of solvent. There is an idea prevalent in geology that the surface waters are prevented from penetrating the crust of the earth below the level of the sea; and that there is no active solution below sea level. This seems impossible or, at least, improbable. If we suppose a tube open at both ends with one end on land and the other submerged in the sea, water poured in the upper or land end would flow out beneath the sea. If the channel is through the rocks instead of a metal pipe the water will flow seaward in the same fashion. Professor Shaler tells of a submarine spring off the coast of Florida whose channel on the land must lie below sea level.* Such springs are known also in other parts of the world.

It should be remembered that the process of concentration here suggested has been in operation for a very long time. The original zinc deposits were laid down in the ocean during the Ordovician or Lower Silurian period, and from the time the beds rose a little above the level at which they were deposited down to the present—we know not how many millions of years—the waters have been passing through these rocks. We have at our disposal a vast period of time in which this agency of solution and redeposition has been at work. In such a process of reasoning we must be on our guard against a certain inference that may appear at first glance to be warranted. It is not to be inferred, for example, that the present subterranean watercourses have been in existence from the beginning. On the contrary the evidence is conclusive that old waterways have been choked up and abandoned and new ones

* Bulletin of the Geological Society of America, 1895, VI, 155.

have been established. For example, we now have exposed at many places on the surface, on the sides of hills, and in the risidual soils stalactitic deposits that must have been formed inside of caverns along ancient watercourses. Many of the brecciated deposits that were formerly loose, open masses through which water could readily move are now closely cemented by the deposition in their cavities of sphalerite, calcite, or dolomite spar.

Miners are familiar with the fact that pipes used to drain mines are often more or less choked and eventually closed by the deposition in them of mineral matter. The accompanying illustration shows a section of a rough wooden box made of inch boards and used for ten years in

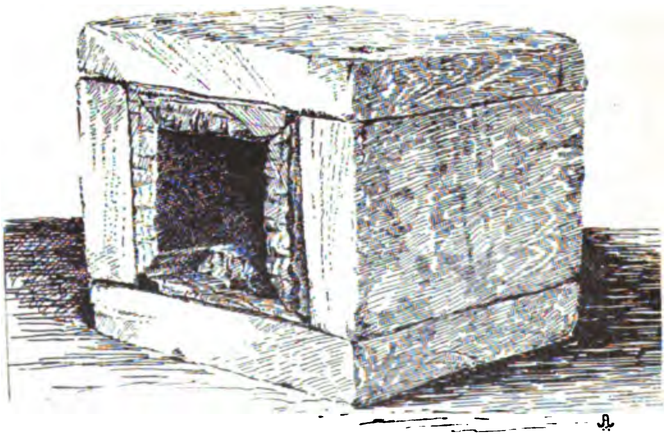


Fig. 4. Wooden water pipe from the Comstock mines, lined with mineral deposited from solution.

the Comstock mines for carrying mine water. After only ten years of constant use this box was lined with a layer of mineral matter half an inch thick. In time it must have been completely closed and the water compelled to seek some other outlet. If the water had been flowing through a heap of stones the result must have been the same—the spaces between the stones forming the waterway must have been closed and the fragments cemented into a breccia.

The conditions shown in the accompanying illustration reproduced from Chamberlin's report on the zinc and lead region of Wisconsin seem to find a ready explanation in the theory here offered for the Arkansas deposits. This

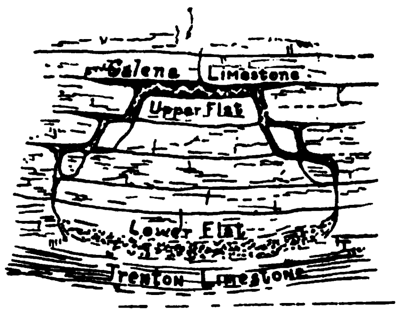


Fig. 5. The ore deposits in "flats and pitches," after Chamberlin.

particular section looks as though the lower brecciated ore body had been formed along an old waterway whose channel had been closed partly by the falling of the roof and partly by the deposition of mineral matter.

Why some ore beds are unaffected.—After such a long period of chemical activity within the rocks, why is it that there yet remain any of the original beds of zinc ores? Why has it not all been made over into secondary deposits? There seems to be two possible explanations of the undisturbed condition of these original disseminated ores. First, the underground waters have not passed through all the rocks alike. Some places have been more and others less affected by such an agency, so that if, for any reason, the underground waters did not pass through the rocks of a given area, those rocks and their minerals would remain unaffected.

In the second place certain of the bedded ores are in a chert so thoroughly compact and impenetrable that this physical character and condition of the gangue rock seems to offer at least a partial explanation of the unaltered condition of the ores.

The relation of synclines to the ores.—If the hypothetical history here assigned the North Arkansas zinc ores is thus far correct, we are forced to conclude that the geologic structure of the region is of the utmost importance in the determination of the present distribution of the ores.

In an elevated region of approximately horizontal or very gently folded sediments, the waters falling upon the ground and soaking into the earth tend to seek the bottoms of the synclinal troughs. The process of ore-accumulation in such a region would therefore tend to carry the ores into the synclines. The rocks of the zinc region although not far from horizontal are gently folded. Wherever folds have been exposed in the zinc mines the bottoms and sides of these folds have been found richer in zinc than the adjacent portions of the same beds. This is a rule to which I know but few exceptions. As illustrating it, attention is called to the Creek Dig at Maryhattiana, the Beatty mines, the Virginia J., the Roberts property, the Lyon Hill mines, the Davy Crockett, and others described in chapter IV.

The inference seems to be warranted that the synclinal troughs should be located and examined for the richer zinc accumulations. Subterranean waters do not, however, always follow synclines. Sometimes they emerge from the crests of anticlines, and at other times they appear to disregard structural features altogether. Ores left by water moving through and deposited in these apparently irregular and uncertain channels would have equally irregular and uncertain distribution.

The influence of faults.—The idea that faults, fractures and breaks of one kind or another are the best places in which to seek ores has had much influence with the prospectors of North Arkansas. Experience has borne them out, too, in the theory that wherever there is a break in the beds, however small, zinc is likely to be found, though

it does not always occur there. If such fractures do contain ores it is because those fractures have afforded convenient paths for underground waters. But it is true and was to have been expected of waterways along fractures, just as it is true of those originating otherwise, that they are not all rich in ores, and some of them contain no ores whatever.

An interesting feature in connection with the faults is that it sometimes happens that the ores have accumulated, not in the faults themselves, but close to them on one side or the other. This is probably due to the fact that when faults are formed by pressing together the beds on two sides of a fracture this pressure sometimes bends the beds near the fault so as to open them along the bedding planes.

When the ores occur along the ancient underground watercourses guided by folds, faults or fractures, they can be located, approximately at least, by a study at the surface of the geological structure. The brecciated deposits (except those upon faults) will not be so easily located from surface structure; they will require prospecting by a system of bore holes or shafts, or by the careful following of the brecciated masses from any exposure uncovered.

In regard to the faults and folds it may be well to repeat here the warning that neither faults nor folds are necessarily straight lines. One should be on his guard against the theory that the ores of North Arkansas, however they may have originated, follow certain fixed directions. There is no doubt but that they do, in certain cases, follow definite lines and that these lines are sometimes as straight as if they had been laid down with a straight-edge, but it must not be inferred that such lines are to be prolonged indefinitely, or that the direction of an ore body on one property is necessarily the direction to be expected of an ore body in another place. Where the ores have accumulatd in fractures it should be remembered that fractures

are never straight very far, and that other fractures in the vicinity are quite as liable to have an altogether different bearing. Where the ores have accumulated along synclinal folds or other structural features the same law holds good; the direction of these structural lines is liable to change at any point, and whether they do change can only be determined by an examination of the geology.

General conclusions regarding the ores.

The following conclusions seem to be warranted:

I. The zinc was originally deposited in sedimentary beds, mostly of organic origin, in which much of it is still found.

II. The growth of the crystals in the original bedded deposits took place prior to the hardening of the enclosing silts.

III. The position of the ores in the beds has been changed more or less since they were originally deposited.

IV. The changes have been going on ever since the original deposition and are still in progress.

V. By means of such changes vertical and other fissures have been filled with ores brought into them by circulating waters from above, from below, and from the sides.

VI. The position of the ores in the secondary deposits has been determined largely by those structural features that have guided the underground waters in their passage through the rocks.

VII. In some cases the accumulations have taken place along synclinal troughs, in other cases, in fissures along fault lines, and in still others in the breccias formed along ancient underground water-courses.

VIII. The subterranean waterways have in many instances been closed by the deposition of mineral matter and the water has been forced into other channels.

IX. The carbonates and silicates are produced by the alteration of sulphide ores mostly in place.

CHAPTER III.

NOTES ON THE FAULTS OF NORTH ARKANSAS.

It will be seen from the preceding discussion that the faults through the zinc and lead region have an important bearing upon the distribution of the ore deposits. The bedded ores have been displaced by them in many instances, while in others the fractured zones of the faults have been the receptacles of ore deposits of later age. Unfortunately it is not possible to describe or even to mention all the faults that affect the rocks of the region in question. Only a few of them have been incidentally located. None of those of Baxter (north of White River), Sharp and Lawrence Counties have been worked out.

The rocks throughout North Arkansas are for the most part horizontal; to this rule there are but few important exceptions, and in the exceptions the bending or tilting of the beds is, for the most part, comparatively gentle.

Faults, however, have performed a prominent part in the disturbance of the horizontality and continuity of the strata of the region in question. In some places these faults are of but local importance, while in other cases a single break may be traced almost continuously for thirty miles or more.

The throw of the faults, though never very great, is sometimes 400 feet or more. The character of the folds found in the vicinity of the faults is sufficiently well shown in the accompanying cuts and plates to require no further explanation in this place.

Attention should be called to the relation worked out mainly by Dr. Hopkins of the two faults near St. Joe: that

to the north has the downthrow on the south side, while that to the south has the downthrow to the north side. This relation of these parallel faults continues for miles. Along this distance it thus appears that a block of the earth's crust less than a mile wide has dropped down 100 to 400 feet along a distance of many miles.

It is often a matter of both practical importance and of scientific interest to know how the faults of the zinc region have been produced, that is, whether they are normal or tension faults, produced by the pulling apart of the broken earth blocks, or reversed faults caused by the pressing together of these same blocks.

In a region as little folded as are the rocks under consideration, it might be expected that tension faults would predominate. And possibly they do, but in reality there are both kinds. The rocks of the region just south of the St. Joe fault are pretty sharply folded, suggesting that

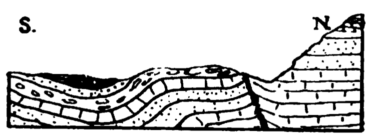


Fig. 6. Section across the St. Joe fault.

they have been pressed against, and the fact that the beds northwest of this fault are higher than the corresponding ones of the southeast suggests that this fault plane dips toward the uplifted rocks—to the northwest.

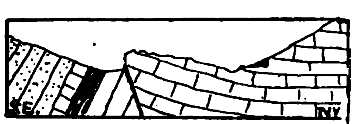


Fig. 7. Section across the fault at the Davy Crockett.

At the Davy Crockett prospects, probably on the same fault, the Ordovician beds have been shoved up until they

rest against the Carboniferous beds. Here the ends of the older strata are bent up like the ends of a sled-runner as they moved up the northwest dipping fault face.

At the Big Hurricane the Ordovician rocks on the north are above the Lower Carboniferous beds on the south and the latter are bent up until they stand at an angle of 42 degrees. The dip of the fault is probably, therefore, toward the north.

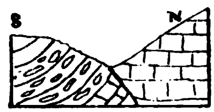


Fig. 8. Section across the reversed fault at the Big Hurricane.

In the vicinity of the Climax mine on Little Rush Créek there is a double fault, the beds are bent and the structure seems to be that shown by the cut accompanying the description of that mine in chapter IV.

Fig. 9. Section across the double reversed fault in the vicinity of the Climax mine.

On the other hand, there are faults in the region that are clearly produced by tension. One of the illustrations accompanying the description of the Morning Star mines shows a small normal fault, and several of those figured by Dr. Hopkins are of this kind. It seems probable, too, that

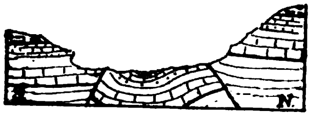


Fig. 10. Section across the supposed double reversed fault on Rush Creek.

the fault on Rush Creek is a double reversed fault and accompanied by a synclinal fold as shown in the accompanying cut.

The faults here spoken of occur in rocks of the Ordovician, Lower Carboniferous and Carboniferous ages; none of the rocks affected by the faults here spoken of are of later age than the Carboniferous. Other peculiarities of the individual faults will be spoken of in connection with the description of each one.

*Faults in Stone County.**—In Stone County there are numerous anticlinal and synclinal folds of local occurrence, noticeably along North and South Sylamore Creeks. They are prominently marked on North Sylamore by the saccharoidal sandstone, which, in a massive layer from 50 to 80 feet thick, forms an irregular wavy line along the hillsides on each side of the creek. A prominent syncline occurs at Mr. Prater's on South Sylamore, 15 N., 11 W., section 21, in the bottom or trough of which occurs an exposure of the Sylamore sandstone and Eureka shale.

A small fault which was traced for two miles occurs in 14 N., 9 W., beginning about the middle of the east side of section 17 and continuing to about the middle of the west side of section 6, the direction being almost due northwest. No topographic feature marks the line of the fault which can only be traced by the line separating the sandstone fragments from the chert fragments. The fault midway of its length has brought the Boone chert on the north up flush with the top of the Batesville sandstone on the south, hence the vertical displacement must be equal to the combined thicknesses of the Fayetteville shale and the Batesville sandstone, which cannot be less than 100 feet. This fault is apparently responsible for the small island of Fayetteville shale and Batesville sandstone lying in the chert area, a half mile northeast, in section 8.

* The remainder of the chapter on faults was prepared chiefly by Dr. T. C. Hopkins, formerly one of the assistants of the Geological Survey of Arkansas, but now of Syracuse University, Syracuse, New York.

On Roasting-ear branch of South Sylamore, 15 N., 12 W., section 7, the northeast quarter, at the mouth of a ravine near Mr. Stephens' house, a fault occurs where the Boone chert on the north side of the fault abuts against the Izard limestone overlain by St. Clair marble and chert on the south side. Owing to the abundant chert debris the displacement could not be measured; it is estimated at about 100 feet. This fault is visible on the hillside east of the ravine and may be traced across the north part of section 7 in a nearly due west direction. It was not located west of section 7.

Fault in Baxter County.—On Spring Creek in Baxter County, in 16 N., 13 W., about two miles northeast of Big Flat, is a fault with the downthrow of 200 or 300 feet on the southwest side. The Boone chert occurs along the creek bank above the crossing of the Big Flat-Mountain Home road. The hill on the south side of the creek is composed of the chert, and capped with the Batesville sandstone. On the north side of the creek is an exposure of 250 feet of Calciferous rocks overlain with chert. The details of the fault on Spring Creek were not traced out, but occurring, as it does, almost directly between the one on Roasting-ear Creek, and the one on Rush Creek, it is possibly in the same line of disturbance.

*The Round Mountain fault.**—The Round Mountain fault was first observed three-quarters of a mile southwest of Round Mountain, in 15 N., 14 W., section 12, 100 yards southwest of the east half mile corner. In a small ravine near the east half mile corner of the section, the Batesville sandstone occurs 40 to 50 feet below the top of the chert which forms the top of the hills immediately south. The Batesville sandstone and Fayetteville shale, which lie approximately flat in this locality, are cut entirely through

* The notes on Round Mountain fault are by Professor J. F. Newsom and C. E. Siebenthal.

by the ravine, and together show a thickness of about 50 feet, which added to the height of the chert in the hills to the south shows a vertical displacement of at least 75 to 100 feet, with the downthrow on the north side.

In 15 N., 13 W., section 7, 200 yards south of the centre of the south half, many Batesville sandstone fragments are found on the north side of the chert hill, 30 to 40 feet below its top. The line of fracture is undoubtedly near this place.

In 15 N., 13 W., section 15, the road leading north from Alco to the Mountain View-Big Flat road passes down a gentle descent from the chert hills it has been following and at a small cemetery passes over a sandy soil with sandstone fragments scattered about. The line of the fault must pass here. The vertical displacement here is at least 50 feet and probably more.

The row of sandstone islands which lies in the chert area north of and along the line of the fault for its entire distance have a well-defined synclinal structure, the common synclinal axis running parallel to the line of the fault. The north edges of these islands are uniformly higher than the south edges. The islands owe their existence to some extent to their synclinal structure, but principally to the protection which results from their being thrown below the chert to the south.

In section 25, same township, and section 30, 15 N., 12 W., the chert hills to the south are obviously higher than the sandstone hills to the north.

In section 33, 15 N., 12 W., near the middle of the west side of the section, the crest of the chert ridge between two tributaries of Panther Branch suddenly descends 30 or 40 feet, the chert disappears, and in its stead are sandstone fragments lying on Fayetteville shale. The vertical displacement is at least 75 feet.

Near the southeast corner of section 33, same township as above, the Mountain View road going westward, forks on a ridge capped by Batesville sandstone and dipping northward. Chert fragments cover the divide which is a hundred yards south and 20 or 30 feet lower. The line of disturbance crosses just south of the ridge and gives direction to it.

In 14 N., 12 W., a ridge of Batesville sandstone extends east and west through the middle of section 2. The west end of the ridge is higher and the whole dips northeast under Cow Mountain. The fault passes through the hollow just north of this ridge. The Batesville sandstone forms the customary bench around the west end of Cow Mountain and, passing up the hollow referred to, disappears under the mountain. The union of the Batesville sandstone on the north with that on the south of the fault is obscured by the debris from the mountain. Appearances in the field favor such a union. Moreover, the fault line, if it extends further, must pass through Cow Mountain, and it is rather hard to conceive how the mountain could have withstood erosion with such a line of weakness through it.

The Round Mountain fault, as described above, is twelve miles in length, the bearing is west-northwest, and the downthrow is to the north. For the reasons set forth above the fault probably has its east end in Cow Mountain, but possibly extends further than Round Mountain on the west.

*The Rush Creek fault.**—When the geology of Rush Creek was first examined in 1889 it seemed clear that there had been a great deal of displacement or faulting of the rocks. The St. Joe marble and Boone chert cap the ridge along the north side of the valley, while the same beds cap

* By J. C. Branner.

the lower hills south of the valley, while in the side valleys entering Rush Creek from the south some of these Lower Carboniferous beds are exposed 350 feet below their outcrops on the ridge to the north. The original idea of a fault having a downthrow of three hundred feet or more on the south side was strengthened by the presence of small faults in the Morning Star and White Eagle mines with their downthrow on the south. Later examinations have raised doubts about the existence of a single large fault. It is possible that the very evident displacement is produced by a series of small faults, or it may be that it is the result of a double fault letting down a block lengthwise of the valley, or it may be due to a closely pressed synclinal or trough-shaped fold, or, most likely of all, it may be due to a combination of faulting and folding.

In the hollow that opens into Rush Creek just south of the Rush store and post-office, the exposed Lower Carboniferous beds show that the rocks are pressed into a sharp syncline. At several places along the northern side of the valley the rocks dip sharply toward the south showing that they are a part of this synclinal fold. Just what

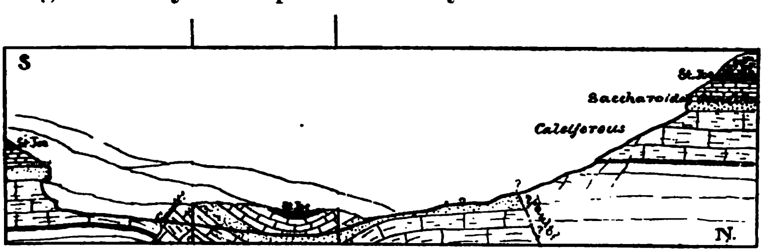


Fig. 11. Section across Rush Creek showing the depressed syncline and the probable reversed faults.

the form and amount of the displacement of the rocks along this valley are can be determined only by a detailed survey. Owing to doubts about the location and even the existence of a large fault at this place the position of the faults shown on the accompanying cut is questioned.

Whatever the displacement may be it is probable that it extends northwest along the upper Rush Creek valley. Nothing is now known of the relation of the Rush Creek disturbance to the faults and folds in the vicinity of the Climax property described in chapter IV.

Water Creek faults.—Two faults cross Water Creek in 17 N., 16 W., in a northeasterly direction. The lower one of the two is in 17 N., 16 W., section 35, 100 yards west of the point where the St. Joe-De Soto (Sylva) road crosses the creek. The downthrow is on the southeast side, and the displacement is about 100 feet. The fault is shown by the red marble occurring in the creek bed near the wagon road on the southeast side of the fault, and by the same rock occurring more than 100 feet above the creek on the north side of the fault. The fault seems to run south 35 degrees west, as it occurs in section 34, the southeast quarter, in the ravine from the south, opposite the widow Langston's; the wagon road in this ravine follows the line of the fault for 100 yards or more, with the limestone and marble exposed on the north hillside, and the Boone chert on the south hillside. The chert debris on the slopes prevents the tracing of this fault out of the Water Creek valley.

Another fault in the Water Creek basin is near the head waters of that stream and crosses not less than three of the terminal ravines. It is quite prominently marked about 100 yards west of the St. Joe-Yellville road in 17 N., 17 W., section 25, the southeast quarter. Immediately south of the fault the Boone chert is the only rock exposed, but the St. Joe marble outcrops underneath it 400 yards further down-stream. On the northwest side of the fault the Calciferous sandstone and limestone are exposed much crumpled and twisted. The chert debris obscures the fault on the tops of the hills on each side of the creek, but that the fault on Barren Fork of Water Creek in 17 N., 16 W.,

section 21, the northeast quarter, is a continuation of the same fault, is shown both by the direction and throw being the same, and by the continuity of the marble outcrop at the same general level around the heads of the ravines on the northwest side and the occurrence of the same rock in the creek bed on the southeast side. The marble on the hill on the northwest side of the fault is 220 feet higher than that in the creek bed on the southeast side, but as the two points measured are more than a mile apart the actual displacement in the rocks may be more or less than this.

The Tomahawk faults.—Prominent faults are noted at four places in the Tomahawk Creek basin. The lowest one in the valley is in 16 N., 16 W., sections 15 and 16, on the lower part of Mud Spring Branch. Its direction is a little north of west and its downthrow is on the south side. South of the fault the Boone chert is the only formation exposed; north of it the saccharoidal sandstone (Caleiferous) overlain by marble and chert forms a prominent ledge along both sides of the ravine for more than a mile.

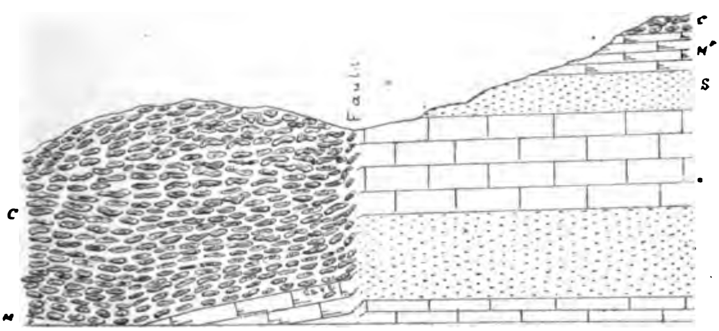


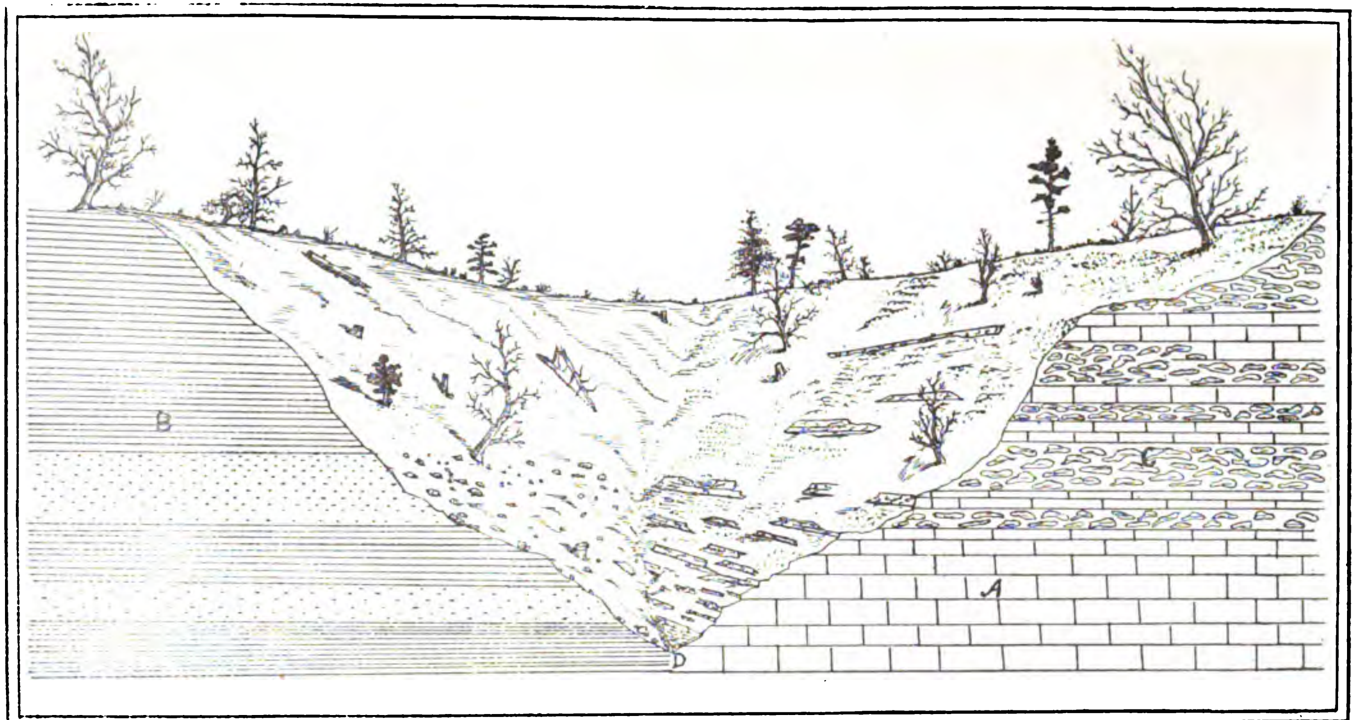
Fig. 12. Section across the fault on Buffalo River near the mouth of Tomahawk Creek.

C, Boone chert. M, St. Clair Marble.
S, Saccharoidal sandstone. N¹, St. Joe marble.
Scale: one inch=100 feet.

The best section across this fault, as shown in Fig. 12, is on the river bluff just east of Mud Spring Branch in the

southwest quarter of section 15, 16 N., 16 W. The marble (M) exposed at the base of the hill on the south side of the fault is the St. Clair (Silurian); the St. Joe marble, if present, being concealed by the chert debris. On the north side of the fault more than 250 feet of Calciferous rocks (S) are exposed, with the St. Joe marble (M) near the top of the hill covered with a thin bed of chert (C). The section shown in the illustration, was taken on the west bank of Buffalo River on the outside of the horse-shoe curve about half a mile down-stream from the mouth of Tomahawk Creek; a bridle path up the bluff from the river is very nearly on the line of the fault.

In 16 N., 16 W., section 8, the southeast quarter of the northwest quarter, in a little ravine from the northwest at Mr. Parks' house is a fault running in a nearly east-west direction with the downthrow on the south side. Plate VII, facing p. 46, shows a section across the fault near the mouth of the ravine, with the ravine in the background. The watercourse follows the line of the fault, the slope on the south side being covered with black Marshall shale and Batesville sandstone boulders, the slope on the north side showing outcrops of St. Joe marble, Boone chert and cherty limestone. The same fault, exhibiting similar phenomena, occurs a short distance west, in the small ravine flowing west to the old copper smelter in the north part of section 7. The fault passes about 100 yards north of the old smelter, and south of the copper mine it is marked in a general way by the bed of black shale on the south side and the Boone chert or Calciferous sandstone on the north side. Faulting also occurs at the copper mine, the throw being much less than in the fault south of the mine, possibly being part of the same break. The same line of disturbance occurs just south of Richard Thompson's house in 16 N., 17 W., section 1, the southwest quarter, but whether at this point it is a fault or a steep monocline was not ascertained.



FAULT IN 16 N., 16 W., SECTION 8.

At Gaines' Spring on the hill west of Tomahawk Creek in 16 N., 17 W., section 2, the south part, is a fault, with the downthrow on the south side. On the north side of the fault a few yards north of the spring the following section is exposed, the rocks being in a nearly horizontal position:

Section on Tomahawk Creek at Gaines' Spring.

	feet
Boone chert and limestone	120
St. Joe marble	80
Calciferous sandstone and limestones	180

On the south side of the fault the spring emerges from a broken mass of Boone chert and limestone which stands at high angles, varying from nearly 90 degrees at the fault to a nearly horizontal position in the little valley from the west less than half a mile south of the spring. The line of fracture is quite plain where some digging by prospectors has been done on the line of the fault. On the hill west of the spring the rocks are much broken.

Another fault crosses Tomahawk Creek just above the mouth of Pine Hollow in 17 N., 17 W., section 35, the southeast quarter. As in all the faults on Tomahawk

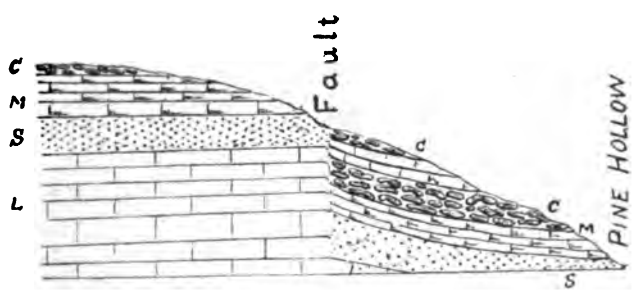


Fig. 18. Section across the fault on Tomahawk Creek at the mouth of Pine Hollow
C, Boone chert. M, St. Joe Marble.
S, Saccharoidal sandstone. L, Calciferous limestone.
Scale: one inch=266 feet.

Creek the downthrow is on the south side, the vertical displacement in this case being about 160 feet. The measurement from the bottom of the marble on the south side at

the mouth of Pine Hollow to the same point on the north side is 200 feet, but as shown on the accompanying figure (14) the rocks on the south side have a strong dip to the southeast, so that the actual displacement is less than 200 feet. A good section across the same fault may be seen in a lateral ravine from the northwest half a mile up Pine Hollow, where the ravine crosses the fault at nearly right angles, with an outcrop of Calciferous rocks overlain by red marble and chert on the north side, and the Boone chert in the bottom of the ravine on the south side of the fault.

A fault occurs in 16 N., 17 W., section 9, at the head of Granny Thompson Hollow, a small tributary of Tomahawk Creek. The Batesville sandstone and Marshall shale outcrop on the south side of the fault and the Calciferous sandstone overlain by the red marble and Boone chert on the north side. The line of fault is on the south side of the ravine at the head, but from a quarter to a half mile east from the head of the ravine the line of fracture crosses to the north side where it is obscured by rock fragments on the hill in sections 3 and 10.

The St. Joe monocline.—A conspicuous landmark and interesting geological phenomenon in the Mill Creek valley, in the immediate vicinity of St. Joe, is a monocline, ex-

Fig. 14. Section across the St. Joe fault.

tending in a northeast and southwest direction about half a mile northwest of the village and dipping sharply to the southeast. A section across it from St. Joe north is shown in Fig. 14, where it will be seen that the rocks on the hill

northwest of St. Joe dip beneath the town. The monocline crosses Mill Creek nearly at right angles a few hundred yards above Morrison's Mill where the rocks are exposed on the bluff on each side of the creek, dipping 10 degrees to 45 degrees down the creek. Away from the creek bluff on the southwest side the monocline is concealed by the broken chert. It shows on the point of the hill on the east side of Mill Creek; it is concealed by detritus in the low ground of the small tributary from the north but reappears on the east side of the ravine, northeast of Mr. Turney's house in section 8, where the chert and cherty limestone have a higher dip than on Mill Creek—70 to 80 degrees south, 30 degrees east. The rocks at this point abut against the sandstone and red marble which are in a nearly horizontal position, the monocline appearing to come to an end.

The St. Joe fault.—The St. Joe fault is about one mile north of the village of St. Joe on the south slope of the dividing ridge between Mill Creek and the south prong of Tomahawk Creek and runs in a nearly east-west direction. The village of St. Joe is on the Batesville sandstone, which, with the overlying shale, extends to the monoclinal fold that lies south of the fault. Figure 15 shows a section from St. Joe to the top of the hill north of the village through both the monocline and the fault. The downthrow is on the south side; a line of levels run by the State Geologist shows the displacement at this place to be 283 feet.

From the zinc mines near St. Joe the fault can be traced east as far as the head of the ravine on the west side of section 9 (16 N., 17 W.), where it is concealed by the chert debris; the fault and monocline appear to meet near the head of this ravine. The wagon road from St. Joe to South Tomahawk Creek crosses the fault 200 feet above the valley and between a quarter and a half mile north of Mr. Turney's house.

Westward the fault was traced into 16 N., 18 W., section 11, the south part, a distance of two miles. It runs very nearly parallel with and from a quarter to a half mile north of Mill Creek. The old Carrollton road crosses the fault 285 feet above the creek. West of the road the fault can be located very accurately in the numerous ravines leading into Mill Creek from the north, by the actual contact of the rocks, and on the dividing ridges between these ravines by the line between the broken chert on the south side and the broken sandstone on the north side. Figure 16 gives a north and south section across Mill Creek in 16 N., 17 W., west part of section 7, half a mile or more west from the forks of the creek, which shows the relation of the rocks at this fault and at the one on the south side of Mill Creek.

The Mill Creek fault.—Another fault has the same general direction on the south side of Mill Creek that the St. Joe fault has on the north side. A section across it is

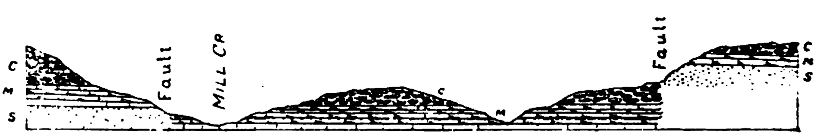


Fig. 15. Faults on Mill Creek, west of St. Joe.
C, Boone chert. M, St. Joe Marble. S, Saccharoidal sandstone.

shown in Fig. 15, where the displacement is 100 feet with the downthrow on the north side. It will thus be seen that Mill Creek, in this part of its course, runs along and close to the southern limit of a depression. The most eastern exposure of the Mill Creek fault is about half a mile west from the forks of the creek on the hill on the south side of the creek in 16 N., 17 W., section 18, where the red St. Joe marble on the north side of the fault, may be seen in direct contact with the saccharoidal sandstone on the south side. The displacement (100 feet) was measured from the bot-

tom of the red marble in the ravine near the creek on the north side of the fault to the bottom of the red marble on the hill on the south side of the fault. The fault can be easily traced westward along the south side of Mill Creek to near the middle of section 14 (16 N., 18 W.). While it is obscured on the hillside in many places by the chert debris, it is very distinct in the numerous ravines on the south side of Mill Creek.

The St. Joe and Mill Creek faults together present a similar phenomenon to the one described as a synclinal fault on Brush Creek (Eureka Springs Sheet). South Mill Creek from its head to its confluence with Monkey Run in 16 N., 17 W., section 18, runs on a depressed area. It differs from the Brush Creek fault in being lower in the geologic series, thus on Brush Creek the Batesville sandstone and shales are on the belt of depression, while on Mill Creek it is the Boone chert, but the Batesville sandstone is on the depressed area on the ridge at the head of Mill Creek. The faults on the head of Caney Creek, 16 N., 18 W., section 8, the south part; on Hurricane Branch of Davis Creek in 16 N., 19 W., sections 11 and 12; are undoubtedly on the same line of disturbance as the Mill Creek fault; while the one on the head of Hurricane Branch, 16 N., 18 W., section 7; 16 N., 19 W., sections 12, 10, 9 and 6 are on the line of the St. Joe fault. The data collected are not sufficient to locate with certainty the continuations of the St. Joe or Mill Creek faults west of 16 N., 19 W., section 6, if indeed it extends further west.

A fault occurs on the south side of Buffalo in 15 N., 18 W., section 8, with the downthrow on the southeast side. The direction of the fault is apparently southwest corresponding in direction with the course of a small ravine, tributary to Buffalo. The Boone chert outcrops on the hillsides on the southeast side of the ravine and the saccharoidal sandstone, limestone and marble on the northwest side.

In 15 N., 19 W., in sections 25, 26 and 35, the rocks show much disturbance and while no fault line was located it is quite probable that there is one or more.

The Caney Creek fault.—A fault crosses Caney Creek near its head and less than a quarter of a mile south of the Marshall and Harrison road, 16 N., 18 W., close to the section line in the south part of section 8, where three short ravines unite. It has a nearly east and west direction with the downthrow on the north side. On the north side of the fault is the gray marble of the Boone chert series overlain by the chert; in the watercourse abutting against this on the south side is the saccharoidal sandstone of Calciferous age, which on the hillsides is overlain by the St. Joe marble and Boone chert. The displacement is estimated to be from 80 to 100 feet.

A quarter to half a mile north of the fault on the Marshall and Harrison road is the Batesville sandstone, which is 210 feet above the line of the fault in the watercourse, and north of which on a still higher level the Boone chert appears again, indicating a fault north of the one just described with the downthrow on the south side.

The Davis Creek faults.—On Hurricane Branch of Davis Creek, in 16 N., 19 W., sections 11 and 12, are two faults. The first one, in the southwest quarter of section 12, and in a branch ravine in the southeast quarter of section 11, has the same direction and throw as the first one described on the head of Caney Creek. The Calciferous sandstone outcrops in the creek on the south side of the fault, and the red marble on the north side.

About half a mile north of the fault last described is another one, with the downthrow on the south side, which has nearly the same general east and west direction. At the head of Hurricane Branch, in 16 N., 18 W., the north part of section 7, the line of fault is nearly identical with the watercourse. Through section 12 (16 N., 19 W.), the

fault, which runs in a nearly west direction, is north of the ravine which has a nearly southwest course. It is marked by the Boone chert outcrop on the south side of the break, abutting against the Calciferous sandstone on the north side.

At the line of fault in section 7 (16 N., 18 W.) east of the spring the chert is much disturbed, the layers twisted and crumpled dipping in various directions and in places much brecciated.

On another tributary of Davis Creek, in section 10 (16 N., 19 W.), is a fault with the same direction and throw on the same side as the last one above. Another similar one, or a continuation of the same, crosses Davis Creek, in section 9 (16 N., 19 W.), where the chert outcrops on the south side of the fault, while 100 yards or more down the creek from the fault the marble outcrops at the water level, but rapidly rises to near the tops of the hills. On the north side of the fault the marble outcrops near the tops of the hills, but dips north five to ten degrees, so that it is at the water level at Yardell.

Through section 9 and the northeast quarter of section 8 (16 N., 19 W.), the fault may be traced by the broken chert on the south side and the broken saccharoidal sandstone on the north side.

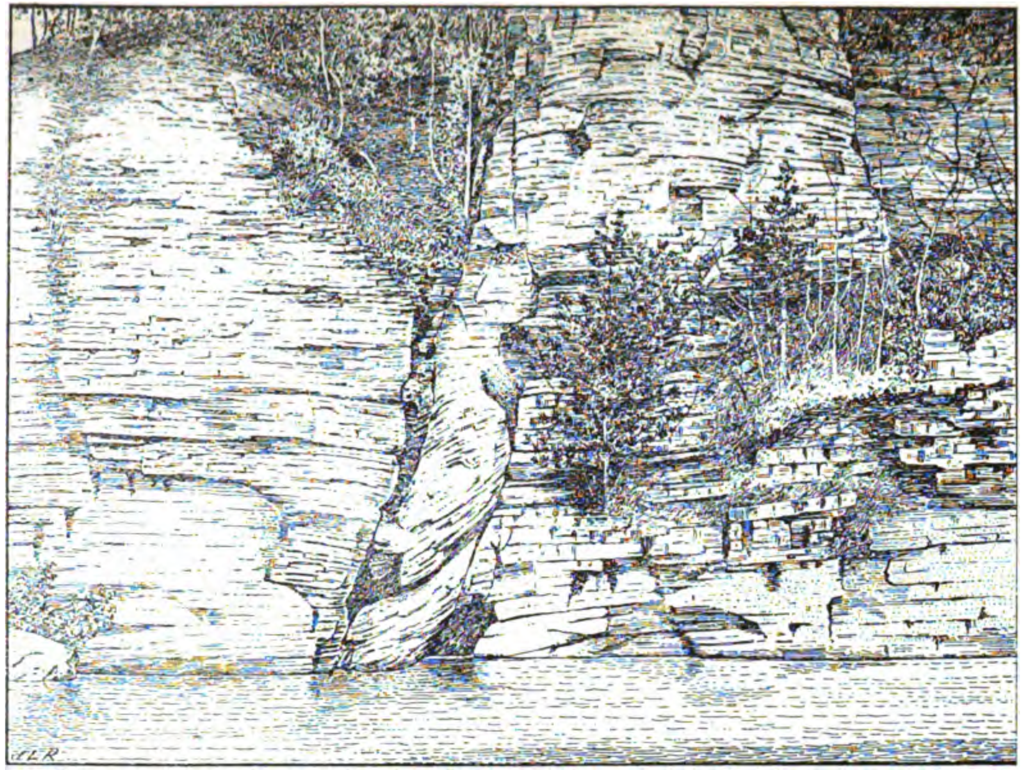
In the north part of section 8 it changes direction locally, following a short ravine in a northeast and southwest direction, where it is marked by the much disturbed gray marble of the Boone chert on the northwest side, and the pyritiferous black shale, overlain by Batesville sandstone, on the south side. On a short tributary of Well's Creek, section 6, the southeast quarter, a fault is plainly visible with the same relative position of the rocks, as the one last described, viz., black shale on the south and gray marble on the north, the direction appearing to be east and west. This fault was not traced further west.

Faults on Big Buffalo River.—Below the mouth of Mill Creek, in 16 N., 20 W., section 5, in the bluff on the north side of Big Buffalo, 200 to 300 yards east of the Jasper-Marble City road, is a compound fracture in the rocks, the details of which are shown on Plate VIII, facing p. 54. The most prominent break is the one on the right of the figure and lowest on the river. The downthrow is on the northwest side where the red marble is exposed at the water's edge; on the southeast side is an exposure of 35 feet of Calciferous sandstone which is overlain by the red marble and chert. The breaks above and west of the ravine are not so conspicuous, and the displacement not so great.

Another syncline crosses the river about three-quarters of a mile below the one just described, in 16 N., 20 W., section 8, in the trough of which no rocks are exposed below the chert, but the marble outcrops both above and below. It is possible that fractures may occur in this syncline similar to the faults above described, if so they are concealed by the debris.

In 16 N., 22 W., section 11, the southwest quarter, up from the mouth of Indian Creek not more than 100 yards, is a fault with the downthrow on the north side, but owing to the fragmental condition of the rocks neither the direction of the break nor the amount of displacement was ascertained. The Boone chert outcrops on the north side and the Calciferous sandstones and limestones on the south side of the fault.

On the north side of Big Buffalo, in 16 N., 22 W., there is a fault just north of the quarter section corner on the line, between sections 10 and 11 on the steep slope on the north side of the road, about 200 yards from the ford. The downthrow is on the south side, and the vertical displacement is probably nearly 400 feet. The Boone chert occurs on the south side of the fault on the point of the hill and in the valley; the Calciferous sandstones and lime-



FAULT ON BIG BUFFALO RIVER SOUTH OF MARBLE CITY.

stones on the north side, outcrop 350 feet above the road, thus showing the displacement to be more than 350 feet.

A fault of similar nature, which is possibly a continuation of the same, occurs in the east side of section 9, near the mouth of Sneed's Creek. The mouth of Sneed's Creek is on the Calciferous rocks which have an exposure of nearly 300 feet at the mouth of the creek. A hundred yards up-stream from the mouth of the creek the Boone chert of Carboniferous age outcrops at the water level.

The first ford of the river below the mouth of Sneed's Creek is dry in time of low water, possibly caused by the waters finding an underground passage through some of the cracks formed by this fault.

Half a mile up-stream from the mouth of Sneed's Creek, on the west side of the river, and a hundred yards below the second ford of the river above Sneed's Creek, is another fault with the downthrow on the north or east side. On the east side of the fault the strata dip down the river so that the saccharoidal sandstone which is exposed at the fault disappears a hundred yards down-stream. On the west side of the fault is a high bluff of Calciferous rocks, the upper part of which is composed largely of saccharoidal sandstone. The displacement is 350 feet or more.

A fault occurs on Sneed's Creek, in the south part of section 5 (16 N., 22 W.), near where the road to Compton post-office leaves the creek. The downthrow is on the south side. A fault was observed on Sneed's Creek above this, possibly in the southwest quarter of section 5, which crosses Sneed's Creek at a low angle, the downthrow being on the south side with the Boone chert outcropping; while on the north side of the fault the saccharoidal sandstone is exposed 100 feet or more, overlain by marble and chert.

At the Chimney Rock mine on the south side of section 7 (16 N., 22 W.), is a fault in which the displacement is

apparently horizontal as shown by the horizontal striæ on the slickensides on each side. There may be a vertical displacement as well which could only be proven by tracing the break to the underlying or overlying rocks.

A fault at the Baker and McGrath mines is described in the notes on the mines.

Three miles up Big Buffalo above Boxley post-office Smith Creek enters from the east; going half a mile up Smith Creek and ascending the mountain to the north, the road passes within a few hundred feet from Carboniferous sandstone on to the Boone chert and limestone showing a fault at this place.

Faults on Little Buffalo River.—Numerous prospecting shafts are sunk along the line of a fracture that occurs in 16 N., 21 W., section 31, in 16 N., 22 W., section 36, and 15 N., 22 W., sections 1, 2, and 11. In some places, as at the Panther Creek mine, the displacement appears to be horizontal, as the striæ on the slickenside walls are horizontal, and no evidence can be seen of any vertical displacement. In other places a vertical displacement is quite plain, as in the south part of section 36 (16 N., 22 W.), where on the hill above an outcrop of 100 feet of Marshall shale is an exposure of 100 feet or more of Boone chert, an underlying formation. At Blue Bluff, 15 N., 22 W., section 1, the southeast quarter of the northwest quarter, the fault has a downthrow of 10 to 15 feet on the southeast side.

Boone County.—In 20 N., 21 W., section 18, near the middle of the section is a fault with the downthrow on the south side, which was noted by Dr. G. H. Ashley, a member of the Survey corps. It is on the northern border of a Batesville sandstone area with the sandstone on the south side of the fault and the Boone chert on the north side.

In 21 N., 22 W., sections 26 and 35, is a marked change in level of the strata; whether it is due to a monocline or fault or both is not clear. Calciferous rocks overlain by

red marble outcrop with a thickness of 200 feet on Raven Bluff, the rocks apparently horizontal, while at the upper end of the bluff, in the southwest quarter of section 26, not over 50 feet of Calciferous rocks are exposed, yet it is not clear how much is concealed in the talus. However, in the middle of section 35 only a mile south of the middle of Raven Bluff the exposure of Calciferous is only from 10 to 15 feet.

Elixir Springs fault.—At Elixir Springs, in 20 N., 19 W., section 36, is a fault apparently local in extent. It shows on the west side of the ravine opposite and a little below the post-office, but does not appear on the east side, probably being concealed by the debris. The downthrow is on the south side, the displacement being from 50 to 75 feet.

The Green Forest monocline.—A large monocline, in general direction south 15 degrees east and dipping north 75 degrees east, occurs in ranges 23 and 24, crossing the Harrison-Eureka Springs road, two miles west of Green Forest. Faults occur in places along this monocline.

It is noticeable in traveling the road from Harrison to Berryville by the general geologic features. From Batavia to Green Forest, by way of the lower or Terrapin road, one is almost constantly in sight of a prominent ledge of rocks, the Millstone grit, south of the road and several hundred feet above it. West of Green Forest this ledge disappears, and two miles west of Green Forest another ledge appears, which is not so thick nor so near the tops of the hills as the other and is composed of the St. Joe marble, a formation which occurs geologically several hundred feet below the Millstone grit.

This monocline is likewise conspicuous on a geologic map. The large Calciferous exposure of the King's River and Osage Creek valleys has no counterpart in the Long Creek valley to the east, which would be the case if the

rocks were horizontal or nearly so. Likewise the Batesville sandstone and Millstone grit areas about Green Forest have no counterparts on the equally high hills west of Green Forest and west of Osage Creek.

While no clearly defined lines of break of any extent were located along the line of Green Forest monocline, it is evident that the rocks are more or less faulted a part of its length. The most southern point noted on the monocline is in 18 N., 23 W., section 15, at the spring from the base of the marble bluff on the east side of the wagon road, and for half a mile or more south of the spring in the valley. It is probable, however, that this is not the southern limit of it.

In 18 N., 23 W., section 3, on the south side of the small tributary from the east the monocline is shown by the ledge of saccharoidal sandstone which has a dip of 18 degrees a little north of east.

In 19 N., 23 W., section 33, nearly one mile east of Osage Creek, in the bed of a little creek from the northeast, the red, St. Joe marble dips north of east 20 to 30 degrees and a small fault, possibly but a few feet displacement, occurs in the creek bed 100 to 200 yards southwest from the marble outcrop.

In 19 N., 23 W., section 20, on the road from Green Forest to Rule post-office on top of the divide between Yocum and Osage Creeks, there is apparently a fault in the rocks. The Boone chert outcrops on the west side of the road, and the Batesville sandstone on the east, overlying which, and not more than fifty feet above the road is an outcrop of Millstone grit. North from the top of the ridge towards Green Forest, the road descends 420 feet over the Batesville sandstone, the line of parting between the chert and the sandstone lying west of the road, and for more than half a mile in sight of the road. The dividing ridge between Yocum and Osage Creeks, through sections

7 and 18 (19 N., 23 W.) is a chert ridge 400 feet higher than the gently undulating region about Green Forest, which is on the Batesville sandstone, the formation overlying the chert. The total change of level produced in the strata at Green Forest is not less than 450 feet, and is probably more than 500 feet.

In 20 N., 23 W., section 31, the marble outcropping in the watercourse near the middle of the west side of the section is 200 feet below the marble outcrop in the southwest corner of the section, the latter outcrop occurring in horizontal layers, the former dipping 10 to 20 degrees nearly east. The outcrop in the watercourse in section 30 (20 N., 23 W.) has a similar sharp dip to the east, and is 350 feet lower than the marble outcrop on Pilot Mountain, in 20 N., 24 W., section 24.

The monocline crosses the Berryville-Springfield road in 21 N., 24 W., section 36, in a ravine a quarter to a half mile east of Indian Creek.

Faults in War Eagle Creek valley.—In the War Eagle Creek valley, in the south part of 17 N., 26 W., the rocks are much disturbed and faulted in a number of places; all the faults so far observed have the downthrow on the south side, and most of them occur near the northern limits of the Batesville sandstone.

In 17 N., 26 W., section 25, the northeast quarter, a quarter of a mile west of War Eagle Creek and immediately west of the Huntsville-Marble road where it turns east, is a fault with the Batesville sandstone on the south side and the Boone chert on the north side, with a clearly marked dividing line between the sandstone and the chert traceable from the valley to the top of the hill.

A fault with similar throw but indistinctly marked occurs in section 23, the southeast quarter; another in section 22, the southeast quarter, where the line of fault is in the Holman Creek valley with the chert forming the

hill on the northwest side and the Batesville sandstone on the southeast side.

In section 28 (17 N., 26 W.), the southwest quarter, northeast of the Hindsville-Huntsville road, is a fault with the Marshall shale on the south side in the valley and the Boone chert on the north side extending to the top of the hill. A displacement occurs on the west bank of Holman Creek in section 32 (17 N., 26 W.), in the southeast quarter.

Faults in upper White River valley.—In the White River valley below its confluence with War Eagle there is a fault on the east prong of little Clifty Creek, in 19 N., 27 W., section 17.

A fault occurs in the Brush Creek valley, in 17 N., 27 and 28 W., extending into 16 N., 27 W. As in the Mill Creek valley west of St. Joe, there are two faults or fractures running nearly parallel with each other, the northern one having the downthrow on the south side, and the southern one having the downthrow on the north side. In some places both fractures are on the same side of the creek, but generally the creek flows between the faults. In most places the lines of fracture are concealed by the fragmentary condition of the rock, yet the presence of the fault is shown by the strip of Batesville sandstone and Fayetteville shale in the bottom of the valley and the hillsides on each side composed of Boone chert, the higher parts of the hills being capped with the Batesville sandstone. This is illustrated in Fig. 16, which shows a section across the faults on the road from the Macedonia church to Fayetteville, from a quarter to a half mile southwest of the church, in 17 N., 28 W., section 22. One hundred yards south of Brush Creek the road passes from the Boone chert to the Batesville sandstone where in the ravine east of the road the chert, sandstone, and shale dip west of south at an angle of 45 degrees and are more or less fractured. West

of the road the line of contact of the sandstone on the south side and the chert on the north side may be traced up the hillside 100 feet or more above the valley and was traced a

Fig. 16. Section across the faults on Brush Creek.
B, Batesville sandstone and Marshall shale. C, Boone chert.

mile west of the road to near the half mile line in the south side of section 16.

On the Goshen road a quarter to a half mile southwest from the ford of Brush Creek the strata have a sharp dip to the north and are also faulted with the downthrow on the north side. The fault is shown directly by the Batesville sandstone abutting against the Boone chert and indirectly by the high chert hill to the south, capped with the same bed of Batesville sandstone that at the fault appears in the valley nearly 200 feet lower.

The fault was traced to 16 N., 27 W., section 5, the northwest quarter, where it is concealed by debris. The big spring at Mr. Parish's in the northwest quarter of section 5, is close to the south fault line, which is quite plain in the ravine west of the spring where the Batesville sandstone and black shale occur on the north side of the fault and the Boone chert on the south side. On the north side of Brush Creek opposite the spring, in 17 N., 27 W., section 33, is the north line of fault, the reverse of the one at the spring, with the sandstone and the shale on the south side and the Boone chert on the north side.

Mr. V. H. Cockrane, a student in geology at the University of Arkansas, has worked out two interesting faults

in 17 N., 29 W. These faults start near the same point in the northeast quarter of section 30 and diverge toward the northeast; one of them follows an approximately straight line from the starting point to the northeast corner of section 16 of the same township and range; the other bends farther south and ends near the middle of section 21, 17 N., 29 W. According to Mr. Cockrane's map which he has kindly allowed us to examine, a wedge-shaped block three miles in length included between these lines has sunk downward at its southwestern end.

From here, according to Professor Purdue, a line of disturbance continues southwestward to 16 N., 30 W., section 20. This is shown by a fault of a few feet downthrow on the east side, showing in the railroad cut at the south end of the trestle just south of Fayetteville, by several faults of small displacement in the city of Fayetteville, by a disturbance of the sandstone (Millstone grit) on the top of the hill in the north part of section 9 of the last named township and range, and in the disturbance of the Batesville(?) sandstone in the creek bed, 17 N., 30 W., section 31, the northwest of the northwest quarter.

Faults in Benton County.—The rocks of Benton County are, as a rule, but little disturbed. Faults are almost wanting, and there are comparatively few well marked folds. It is true that some of the exposures of the Eureka shale, as on Spavinaw Creek, result from slight undulations of the strata, but even these are rare.

There is a small fault, the extent of which is not known, on the east prong of Little Clifty Creek, in 19 N., 27 W., section 17, the southeast quarter, about a quarter of a mile below the big spring. The line of fracture is clearly visible on the southwest bank of the creek, opposite the mouth of a small tributary which enters it from the northeast. The displacement is estimated at 50 feet, with the downthrow on the south side. On the north side

the saccharoidal sandstone is exposed, dipping 10 or 15 degrees to the southeast. Abutting against the sandstone on the south side of the fault is the limestone at the base of the Boone chert formation, dipping from 5 to 8 degrees in the same direction. The line of fracture can be traced a short distance up the tributary by the saccharoidal sandstone exposure on the northwest side, and by the limestone outcrop close to the watercourse on the southeast side. In less than half a mile, however, the fracture is concealed by the broken chert. The dip, too, is noticed for only a short distance up-stream (above the fault), the rocks soon regaining a comparatively horizontal position. Down-stream from the fault the sharp south dip continues for nearly a mile, the Ordovician rocks reaching a height of 100 to 125 feet above the creek in section 17 (19 N., 27 W.), the west half, but again falling, on account of a bend in the creek, to 15 or 20 feet in section 18, the south half. In the west half of section 18, the Ordovician rocks are exposed to a height of over 200 feet, and the creek flows northward against the dip of the rocks. On account of the presence of the chert debris, which almost completely conceals the strata in places, it is impossible to trace so small a displacement through the hills. Gentle folds occur on the west prong of Little Clifty Creek to the west, and on Big Clifty Creek in Carroll County, to the east, but no displacement has been observed at either place.

A few faults and folds are described by Professor Simonds in his report upon the geology of Washington County.*

* The geology of Washington County. By F. W. Simonds. Annual Report of the Geological Survey of Arkansas for 1888, Vol. IV, pp. 113-118. Little Rock, 1891.

CHAPTER IV.

THE MINES AND MINING INDUSTRIES.

HISTORICAL.

The lead smelters.—Owing to the demand of the pioneers for lead and to the comparative ease with which the ore could be smelted, it was in the nature of things that the lead of the Ozark regions should be generally known long in advance of the zinc deposits. The valuable mines of southeastern Missouri early induced exploration for lead in the region of the upper White River. In December, 1818, Schoolcraft, the explorer and ethnologist, made his historical trip from the lead mines of Potosi across southern Missouri to the headwaters of White River, and after a brief exploration of the region, descended the White River to Batesville, and returned to Missouri across Lawrence County. He is the first writer to record the occurrence of lead in North Arkansas.*

He mentions its being known "at the Bull Shoals and on Trimble's plantation on White River" (p. 61), and "on the Strawberry River,† in Lawrence County" (p. 60). At that time there were very few white settlers in the upper White River Valley, and none at all, according to Schoolcraft, above Holt and Fisher, who then lived on White River in what is now Taney County, Missouri.‡

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* A view of the lead mines of Missouri, etc. New York, 1819, pp 60, 61, 62, 112, 168, 196.

† See also Journal of a tour into the interior of Missouri and Arkansaw. By Henry R. Schoolcraft. London, 1821, p. 70.

‡ Scenes and adventures in the semi-Alpine region of the Ozark Mountains of Missouri and Arkansas. By H. R. Schoolcraft, p. 93, Philadelphia, 1853.

It goes without saying that there was no mining of zinc in Arkansas territory in those days, and if there was any lead mining it was to supply the rifle balls required by an exceedingly sparse population.

In 1834 Featherstonhaugh, geologist of the United States government, passed through the Sharp and Lawrence counties' end of the zinc and lead region of North Arkansas. In one of his publications he makes mention of a lead mine that had "been opened somewhere up the Strawberry River."*

Little or nothing has been recorded of the development of the lead mining and smelting industries of the region. What is now known of it is largely tradition. The following information has been picked up here and there, but there has been no opportunity to verify it.

In 1851 or 1852 there is said to have been a lead smelter on West Sugar Loaf Creek in 20 N., 19 W., section 23, just west of Philip Moore's place. It was in charge of William Bennett. The pig lead from this smelter was shipped to Springfield, Missouri, by wagons. The low price of lead is said to have caused the closing of the works.

Owen tells of the attempt made (in 1857?) by Mr. Jewell to smelt four tons of lead in a log furnace.†

Before the civil war there were two lead smelters two and a half miles east of the town of Lead Hill, Boone County, and another one in 20 N., 19 W., section 27. The one in section 27 was torn down by Mr. Fine, who formerly owned the land. The lead smelted here came from 20 N., 19 W., section 23.

In 1871 to 1873 there was one lead smelter run by Colonel Childers at Marr's Mill about a quarter of a mile

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* Excursion through the slave states. By G. W. Featherstonhaugh. p. 88. New York, 1844.

† First report of a geological reconnoissance. By D. D. Owen, p 52. Little Rock, 1858.

northeast of Lead Hill; and another owned by an Illinois company was about three miles southeast of Lead Hill, Boone County. These smelters near Lead Hill were operated in 1873 and 1874. The ore was mostly gathered as "float" in the vicinity of the smelters, but there were some shafts put down to a depth of 40 feet. There was one 40-foot shaft on Short Mountain. The pig lead was hauled to Springfield and Marshfield, Missouri. The decline of the price of lead stopped operations. These two Lead Hill smelters are reported to have produced 104,600 pounds of pig lead. The ore is said to have yielded from 72 to 83 per cent. of metallic lead.

In 1876 and 1877 on Cave Creek, Newton County, about 600 feet south of Cave Creek post-office, there was a lead smelter belonging to the Boston Mountain Mining and Smelting Company—an Illinois company. It was in operation a year and a half or two years. The lead was mined on Cave Creek, was smelted at this furnace and hauled to Russellville on the Little Rock and Fort Smith Railway and shipped thence to Pittsburg, Pennsylvania. It is said that four or five teams were employed in hauling the lead for about one year, and that several car loads of pig lead were shipped. This company sold out to the Granby Mining and Smelting Company.

About 1878 a lead smelter is said to have been operated in Newton County in 16 N., 22 W., section 18, by Mr. Vipon. It is reported that fifty tons of pig lead were produced by and shipped from this smelter.

In 1882-3 the Missouri and Arkansas Mining and Prospecting Company operated a smelter on Big Buffalo River south of Boxley. They are reported to have produced 80,000 pounds of pig lead which was hauled to the railway at Eureka Springs.

In 1889 William Bennett is said to have put up a smelter in Newton County in 16 N., 23 W., section 26.

Early zinc mining.—Of the early history of zinc mining and zinc smelting there is little to be known. It should be remembered, however, that zinc mining, even in so old a zinc producing state as Missouri; did not begin much more than thirty years ago.

In 1857 a zinc smelter was erected at Calamine in Sharp County, and in addition to what the company smelted they shipped about 100 tons of zinc ore—the carbonate. The company ceased operations at the outbreak of the civil war.

In 1871-2 a smelter was again put up at Calamine and was operated for about six months. Only the carbonate ore was used. No trustworthy statistics of the output of the mines of the calamine region or of the smelter can be obtained.

Prospecting in the western part of the zinc region began in a very modest way about the year 1886. The early prospectors were men of small means and large faith. It is almost impossible to realize to-day the difficulties they had to contend with. A short time ago very few of the people living in the zinc region knew zinc ore when they saw it, and fewer still believed that it had or ever would have any value. The prospectors were generally looked upon as unbalanced, were openly derided, and in some instances were compelled to defend themselves *vi et armis* against attacks made for the purpose of driving them out of the country.

In contrast with this modest beginning was the rush into this same region in 1899, when every conveyance going into the zinc region was literally crowded for months by miners and prospective miners entering this new field.

INTRODUCTION TO THE NOTES ON THE MINES AND PROSPECTS.

It is of the utmost importance that we should know *what to expect* of our ore deposits:—where they are to be looked for, and in what forms they are likely to occur. These general laws could be made out only by the examination and study of all the type deposits of the region. These can be seen best at the mines and prospects where fresh openings have been made in the rocks. In the course of our study of the geology of these ores visits have been made to many of the openings through the zinc and lead region. In some cases these visits have been repeated for the purpose of verifying former observations, or of seeing the results of later developments. It has been a physical impossibility, however, to visit all the openings, claims and outcrops. It should likewise be distinctly understood that these examinations were not made for the purpose of passing judgment upon the various properties. If there were doubt about the *existence* of zinc and lead in the region, it would be our duty to say something about values, but the existence of these ores is not, and cannot be questioned. When it comes to the matter of the comparative values of the various mines and claims the question is no longer a public one but is a matter for private investigation and for private enterprise.

It cannot therefore be too emphatically stated or too constantly kept in mind that the properties mentioned in this report are by no means the only promising ones in the region under consideration. Those spoken of have been visited partly because they were more or less convenient of access and partly because their existence was called to the writer's attention. There is no doubt but that some of the properties of North Arkansas have come to be talked about somewhat beyond their merits, while others quite as valuable or even of greater value are unheard of or but little known, because the owners are modest and unobtru-

sive, and are depending upon the value of their properties alone to settle the estimate in which they should be held. It is always a pleasure to see fine bodies of ore, but it sometimes happen that these rich properties throw but little light upon the problem in hand; on the contrary, it sometimes happen that the great questions are solved by exposures upon properties of little value. The fact then that one property is mentioned and another is not mentioned must not be interpreted to mean anything more than that one of them was visited and the other was not.

In regard to the illustrations showing the method of occurrence of the ores at several of the mines, it should be explained that these drawings are made directly from the samples and that they are for the sole purpose of showing the origin or genetic relations of the ores, and not to show their richness. None of these samples would be considered rich at the mines from which they were taken.

In the following descriptions and notes some difficulty may be experienced with the names of the claims owing to the fact that many of the old claims have been abandoned and new ones have been entered on the same ground under new names. The locations by sections given in the report cannot always obviate this difficulty because the claims or properties are often much smaller than the smallest divisions that it is found practicable to use in speaking of locations, and there has not been time since the last examination of the region was made to look up and verify the names and locations of claims. In other cases a single property is made up of a large number of fractional divisions lying in several sections and often in more than one township and range. It is neither convenient nor necessary to give full descriptions of such properties.

In certain instances the notes on the mines have been made by persons other than the writer. In these cases the

name of the assistant who made the observations is given at the end of the description of the property. Some of the properties have been examined by more than one person: we have found it more convenient to use our own notes in these cases owing to our great familiarity with them, and to add the new information gathered by Professor Purdue.

Many of the properties spoken of are claims taken up on government land. If we had a map showing all the openings made in search of zinc and lead and showing at the same time the land belonging or lately belonging to the Government we should be struck by the fact that there seems to be but little ore on the deeded land. This is due to the fact that it is necessary, in order to obtain a patent upon government land, to mark off a claim and to do a certain amount of assessment work upon it every year for a given number of years. Deeded land containing mineral deposits is held under other titles, and it is not necessary to do assessment work in order to hold it. For this reason but little has been done to find out whether or not there are valuable deposits of zinc and lead upon the deeded lands of the zinc region. As a rule the owners are disposed to let the miners develop the region around them, hoping that with the development of mining in the district the value of their property may appear. This statement is made, not to find fault with the land owners, but to explain why so little has been done to show up the ore deposits over a very large part of the zinc region.

The words "mine," "prospect," "claim," etc., employed to designate the properties spoken of in this report are used without reference to nice distinctions of meaning. It may be that some of the properties spoken of as prospects might properly and quite justly be called mines, while some that are called mines are only prospects.

NOTES ON THE OPENINGS NORTH AND WEST OF DODD CITY.

The Carrollton lode claim is on Rapid Creek (or Sweet Hollow) in 19 N., 21 W., section 2, the northeast quarter. The opening is on the slope of a hill in horizontal Calciferous rocks, 58 feet below the base of the St. Joe marble which crops out near the top of the hill above.

There is an open cut 40 feet by 10 feet following the bedding of the dolomites into the hill. In the soil and clay are found large spongy masses of zinc carbonate. This zinc ore is found opposite one particular bed, which bed is often coated over with botryoidal layers of the smithsonite. Lumps of partly decomposed sphalerite are found in this same stratum.

The Low Gap mine is in 20 N., 19 W., section 8, the north half of the section. The openings are in brecciated horizontal Calciferous limestones about sixty feet below the St. Joe marble. The development consists of a cut 30 feet long and 8 feet wide, running S. 30 degrees E. into the hill, with a tunnel 15 feet long at its inner end. The cut and tunnel are both in finely brecciated limestone. The ore is galena and smithsonite, occurring together in the breccia and confined to a horizontal streak about two feet thick and showing only in the south wall of the tunnel and

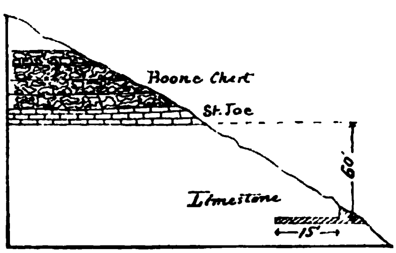


Fig. 17. Section at the Low Gap mine.

around to the middle of the inner end wall. This streak is rich in galena, and carries a good deal of smithsonite. The only ore showing in the open cut is a small amount of

smithsonite near the surface. Sixty feet south of the tunnel and on the same level with it, is a cut 40 feet long, 5 feet wide, and 6 feet deep, following a clay-filled cavern in the limestone, and running N. 40 degrees E. There are on the dump at this place a few boulders bearing blende and evidently taken out of the clay. The limestone of the walls of this cavern carries no ore. (A. H. Purdue, 1900.)

The Bonanza mine, Boone county, is on the headwaters of Upper Sugar Loaf Creek, in 20 N., 19 W., section 21, the northeast and southwest quarters of the northeast quarter. The various openings are in the Ordovician rocks, chert and highly siliceous limestone. In the northeast part of the northeast forty of section 21 is a shaft 69 feet deep. It penetrates siliceous limestones and chert containing numerous cavities lined with quartz crystals and small quantities of zinc carbonate. About 450 feet southwest of the deep shaft but in the same forty is an open cut from which ore has been shipped. The ore occurs as zinc carbonate and blende in a chert breccia, the carbonate forming the cement of the breccia in places; in other places quartz forms the cement. About 300 feet southwest from the last opening and on the southwest forty of the northeast quarter of section 21 is another opening similar to the last, yielding a similar ore. Some ore has been shipped from this cut. A few yards southwest from the last opening described and a little lower on the slope of the hill is the main opening of the "Bonanza eighty" from which most of the ore that has been shipped was taken. In this opening the Ordovician chert is in places stratified, in others brecciated and broken. Near the bottom of the opening and about three feet below the surface is a soft, porous, light-colored rock in regular but not continuous layers. The ore on the dump is zinc carbonate in chert breccia which also contains fragments of saccharoidal sandstone. Numerous cavities of various sizes occur in the rock, which cavities

were at one time filled with zinc blende but are now empty or filled with red clay. Partial analysis was made of specimens of this red clay, and it was found that it contained 1.01 per cent. of metallic zinc. It is therefore not a pure tallow clay, but a mixture of tallow clay with ordinary clay derived from the decomposition of the rocks.

N. 70 deg. E. about 300 feet from the last opening described is a wall-like formation of chert breccia from two to seven feet high.

Mr. O. E. Hines of Lead Hill says that in 1886 he shipped 33 wagon loads (one wagon load equals 1040 pounds) of ore from the Bonanza mine, and two wagon loads from the Singleterry shaft down White River to Batesville and thence by rail to St. Louis, Missouri.

In 20 N., 19 W., section 20, the southwest of the northeast quarter, are four openings known as tunnels numbers 1, 2, 3, and 4, in which some zinc silicate has been found in the hard siliceous rocks of Ordovician age. (T. C. Hopkins, 1892.)

A prospect in 20 N., 19 W., section 15, is on the top of the hill between Sugar Loaf Creek and Lead Mine Creek. It consists of an open cut 20 feet by 15 feet, 6 feet deep. The rock is Ordovician limestone, rich in smithsonite. It is reported that ore outcrops in several places on this hill at a lower level along Sugar Loaf Creek. (A. H. Purdue, 1900.)

The Smith property is in 20 N., 19 W., section 23, the northwest quarter of the northeast quarter. There are two small openings ten feet above a branch of Sugar Loaf Creek showing zinc blende, smithsonite and galena in small pockets. These openings are apparently at a lower geological horizon than the others in the vicinity, and are in fact the lowest at which I have noticed galena. Mr. R. R. Jackson, who has prospected a great deal in this vicinity, says there are three ore-bearing beds above this and

one below it. The principal openings in this vicinity are said to be in the topmost stratum. Some galena is reported still higher up, only about twenty feet below the St. Joe marble. (A. H. Purdue, 1900.)

The Cave mine (*or Singleterry mine*) is on the south side of a hollow draining into Sugar Loaf Creek in 20 N., 19 W., section 26, the northeast quarter of the northwest quarter. The rocks in which the openings are made are horizontal Calciferous beds in the sides and bottoms of the valleys with the St. Joe marble and the Boone chert overlying them. The openings are on the side of a hill facing northward and 70 and 80 feet above the bottom of the gulch. They consist of a shaft 83 feet deep, a drift 100 feet long, and an open cut 75 feet long.

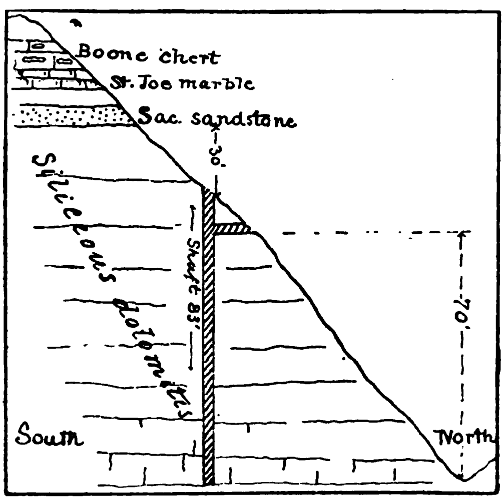


Fig. 18. Section at the Singleterry mine.

The rocks struck in these openings are cream-colored to dark gray, almost black, dolomites and porous siliceous rocks. The light gray siliceous dolomite or "cotton rock" from this shaft was analyzed and found to have the following composition:

Analysis of siliceous dolomite from the Singleterry shaft.

P. Allaire, Analyst.

	No. I	No. II
Silica, SiO_2	12.21	12.18
Iron, Fe_2O_3	0.96	1.01
Alumina, Al_2O_3	1.10	1.16
Lime, CaO	26.04	25.95
Magnesia, MgO	18.02	18.10
Carbon dioxide, CO_2	41.67	41.60
	100 00	100.00

Both zinc and lead are found in these openings, but most of the lead came from dolomite in the bottom of the shaft. The zinc occurs both as blende and as zinc carbonate, and is associated with crystalline calcite. Where the zinc blende has weathered the adjacent calcite contains small lumps of malachite.

The Ayers cut is in 20 N., 19 W., section 26, the southeast quarter of the northeast quarter. The rocks are the Ordovician limestones that here have an east dip of about four degrees. The principal development consists of an opening 20 feet by 12 feet, 7 feet deep. This is on the same hill as the Jones openings and is at the same elevation. The ore is galena in small amounts, occurring in thin veins in the joints of the limestone. There are several other small openings at the same level, all producing galena. (A. H. Purdue, 1900.)

The Combination Lode is northwest of Elixir in 20 N., 19 W., section 26, the southeast quarter, on the headwaters of Upper Sugar Loaf Creek. The rocks are Ordovician about the openings, but the St. Joe marble crops out towards the tops of the hills and over this is the Boone chert.

There is an open cut on the west slope of a hill, 12 feet high on the inner face, and near this inner face and sunk on the floor of the cut is a shaft 36½ feet deep. The rocks penetrated are quartzites and siliceous Ordovician dolomites, some of them brecciated and some of them much de-

composed. The breccias are cemented with chert-like material and zinc carbonate. Similar rocks without the zinc occur further up the hill above the shaft. The ores found are zinc blende and zinc carbonate. So far as developed, however, the zinc blende is not very abundant. The carbonate has been deposited in the numerous small cracks in the rocks and later the rock has been dissolved out leaving a very open textured carbonate ore. In some places thin layers of quartz crystals have covered the rock fragments in this same fashion.

The Empire Lode is in 20 N., 19 W., section 26, the southeast quarter of the southeast quarter. The rocks are horizontal Ordovician limestones full of small quartz-lined cavities, and probably at the same geologic horizon as the Ayers, Jones, and Bailey prospects.

Opening No. 1 is about 20 feet higher than the opening on the Ayers property. The development is an open cut into the hillside 35 feet by 20 feet, 3 feet deep. The rock taken out is very rich in smithsonite, the ore occurring in joints and in the cavities. About 12 tons of ore rock are now on the ore heap. There is also a small amount of zinc blende.

Opening No. 2 is at about the same level and in the same kind of rock as No. 1, but the rock is much brecciated. The opening is 30 feet by 40 feet with a 10-foot face at the inner side. The ore is smithsonite in abundance, cementing the breccia. In the cut a mass of rock 10 feet by 15 feet by 8 feet has been left in place and is very rich in smithsonite. The rock of the inner face contains no ore except in the topmost four feet. The rock in the bottom of the cut is everywhere lean in ore. There are 10 or 12 tons of ore on the dump besides that in place in the cut. (A. H. Purdue, 1900.)

The Jones prospects are in 20 N., 19 W., section 25, west half of the northwest quarter. The rocks are hori-

zontal Ordovician limestones, and the ore-bearing bed appears to be the same as that at the Bailey and Oklahoma properties. Two small prospect holes on the hillside 40 feet above the creek show small amounts of galena and some smithsonite in limestone. One hundred and fifty feet south of these openings is an open cut 10 feet by 12 feet, 4 feet deep, which has a small amount of galena scattered through the limestone in the joints, and also in the solid rock. A hundred and fifty feet still further south and on the same level is an open cut in limestone 25 feet by 8 feet, 10 feet deep at the inner end. A small amount of galena is found in thin sheets in the joints of this rock. (A. H. Purdue, 1900.)

The Saturn placer claim is on the north face of a hill in the Sugar Loaf drainage, in 20 N., 19 W., section 25, the southwest of the northwest, and section 26, the southeast quarter of the northeast quarter. The rocks are the usual Ordovician sediments in horizontal beds—mostly cream-colored dolomites. There is one pit six feet deep; a hundred feet east of the pit is an open cut 65 feet long and four feet deep. The ores are both zinc and galena; some of the galena was found as loose cubes in the surface soil of the open cuts.

The Buck Hollow prospects are in 20 N., 19 W., section 25, the northeast quarter of the northeast quarter. There are seven openings on both sides of a hollow, all made in horizontal, Ordovician limestones by putting in a

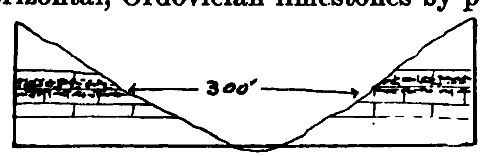


Fig. 19. Section at the Buck Hollow prospects.

few shots. They all show smithsonite in abundance and are at the same geological horizon as the Empire Lode, the Jones, the Bailey, and the Ayers prospect. (A. H. Purdue, 1900.)

The Bessie is in 20 N., 19 W., sections 27, 34 and 35. It consists of several openings in horizontal and more or less decomposed beds of Ordovician chert, limestone and breccia.

Opening No. 1 is on section 35, the northwest quarter of the northwest quarter, about a hundred feet above the creek, and consists of an open pit in the soil from which loose flint rock was taken, carrying smithsonite with some galena and zinc blende, and a little iron pyrites.

Openings 2, 3, and 4 are each small holes made by one or two shots. They are all on the same level as No. 1 and all expose rocks rich in smithsonite.

Opening No. 5 is an irregular shaft 12 feet deep following a vertical fissure. This fissure is from three to twelve inches wide, and runs north and south. There is no displacement of the rocks on opposite sides of the fissure. The ore found at this shaft is galena, occurring in a two-foot stratum at the top of the shaft; no ore has been found

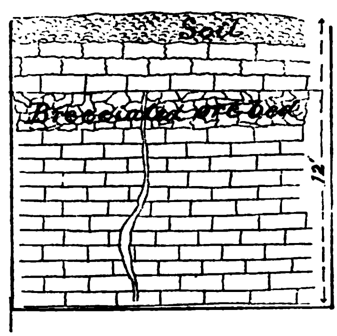


Fig. 20. Section in opening No. 5 at the Bessie.

below this. The stratum bearing the galena is much broken and decomposed. The galena occurs in small pockets from half an inch to three inches in diameter, and in veins associated with a large amount of calcite. No zinc has been found at this place excepting a small amount of smithsonite.

Opening No. 6 is a small pit made by a few shots at the same geological horizon as the others. Half a ton of smithsonite and some galena have been taken from this pit.

Opening No. 7 is on section 27, the southeast quarter of the southeast quarter. It is an open cut on the hillside 75 feet above the creek and on about the same level with all the other openings. The cut is 8 feet by 10 feet with a 6-foot face at the inner end. It is in limestone, much fractured and decomposed, and containing an unusual amount of calcite. The ore is galena, zinc blende and smithsonite, imbedded in calcite. The lead and zinc are usually separate but they sometimes occur together. There are said to be twenty-five or thirty other openings on this property, all about the same level as those described. (A. H. Purdue, 1900.)

The Oklahoma claim is in 20 N., 19 W., section 36, the northeast quarter, and section 25, the southeast quarter of the southeast quarter. The openings on this property are forty feet above the creek, and apparently at the same geological horizon as the Bailey outcrops, that is in horizontal Ordovician beds of cherty limestone, but apparently these beds in the Oklahoma are from 40 to 50 feet higher than the outcrops on the Bailey. They are, however, like the Bailey outcrops, from 75 to 100 feet below the St. Joe marble. The development consists of a cut 50 feet along the hillside and 12 feet wide, averaging 2 feet in depth. The ore is smithsonite with some blende in cherty limestone, and occurs in good quantity so far as the development goes.

Opening No. 1 is an open cut forty feet above the creek level, 10 feet by 10 feet, 4 feet deep, and apparently at the same geological horizon as the Oklahoma and Bailey openings. The ore is mostly smithsonite, with some blende. There are about four tons of ore-bearing rock on the dump.

Opening No. 2 is 150 feet northeast of and on the same level as opening No. 1. It is an open cut in the face of the hill 6 feet by 18 feet, 7 feet deep at the inner end. The ore is smithsonite, with some blende. There are about ten tons of ore on the ore heap.

Opening No. 3 is an open cut and a tunnel 300 feet northeast of No. 2, running S. 30 degrees E. into the hill.

The open cut is 7 feet by 50 feet, and the tunnel is about 60 feet long. Both cut and tunnel are in hard, porous limestone, very similar to that in which the Big Star ore occurs. The cavities are lined with minute quartz crystals; a few of these cavities contain ore. The rock through the whole length of the tunnel contains very little ore. There are four or five tons of ore rock on the dump, which seems to have come mainly from the open cut. The ore is almost wholly zinc blende.

Opening No. 4 is an open cut 4 feet by 10 feet, 5 feet deep at the inner end. It is on the same level and in the same bed of rock as opening No. 3. The rock contains a small amount of zinc blende in the cavities.

Opening No. 5 is an open cut running S. 60 degrees W. into the hill. It is six feet wide, forty feet long, and ten feet deep at the inner end. It appears to be at a somewhat lower level than the other openings on the property and also lower than those of the Oklahoma. No ore is now to be seen about the cut.

There is a 20-foot shaft in cherty limestone on the hillside 75 feet S. 40 degrees W. from the cut. It is said that this shaft produced a small amount of zinc blende. (A. H. Purdue, 1900.)

The Bailey outcrops are in 20 N., 18 W., section 30, the southwest quarter. This property consists of 170 acres upon which the zinc-bearing bed outcrops. There are no mine openings, but the ore is displayed along the sides of the valleys of Sugar Loaf Creek. Two of these outcrops were examined. The horizon of the ore is about a hundred feet below that of the St. Joe marble.

Outcrop No. 1 shows smithsonite for a horizontal distance of sixty feet along the face of the hill. The thickness of the ore-bearing stratum is about five feet. The rock in which the ore occurs is cherty limestone, and is about ten feet above the creek.

Outcrop No. 2 is in every way similar to No. 1, except that it is twenty feet higher. It can be traced for 225 feet along the face of the hill. There are not exposures enough to display the geological structure and it is therefore not clear at present whether this difference in height of the two outcrops is due to the bending or the faulting of the beds. (A. H. Purdue, 1900.)

The Idlewilde claim is in 20 N., 18 W., sections 30 (S. half of S. E.) and 31, north half of the northeast quarter. When visited in December, 1891, there was an open cut on the south face of a hill twelve feet above the bottom of the gulch. This cut is 45 feet long and 8 feet deep at the inner end. It is partly in soil, but a good deal of blasting has been done in the horizontal Ordovician rocks which are siliceous dolomites and cherts. The ore found was chiefly zinc carbonate coating the rocks along and near the outcrop of the zinc-bearing bed.

Further up the gulch is another opening called the "pot-hole" N. 45 deg. E. from the open cut. It is near the top of a little ridge; the opening is a pit 7 feet by 4 feet and 7 feet deep on a fault line. On the upper side of the fault the rocks are siliceous dolomites and on the lower slope they are decomposed green and brown spongy siliceous dolomites. The surface is strewn with nodules of banded chert. Crevices in the hard rock near the surface are coated with zinc carbonate. The ore is good but there is not much of it.

The New Era claim is in 20 N., 18 W., sections 29 (N. W. of S. W.) and 30, northeast of the southeast. The rocks are horizontal siliceous Ordovician sediments, but rough

and jagged on the outcrop. There is a shaft 20 feet deep (Dec., 1891). Near the surface the rocks are coated here and there with zinc carbonate; at greater depths the rocks are straw-colored and gray magnesian limestones or dolomites having cavities lined with quartz crystals. The slope of the hill below the shaft is thickly strewn with "float mineral."

A pit about 30 feet west of the shaft and under the side of the siliceous ledge is covered with zinc carbonate.

The Ben Harrison mine is in 20 N., 18 W., section 25, southwest quarter. The development consists of a shaft 75 feet deep and two drifts as shown in the accompanying drawing. The development is in a fault plane with a

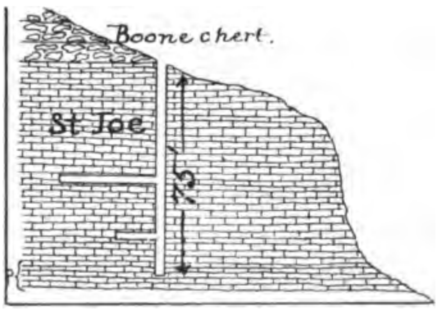


Fig. 21. Section at the Ben Harrison shaft.

downthrow of about 15 feet on the east side, and is in the St. Joe marble (Lower Carboniferous).

The ore is chiefly galena, though there is a small amount of zinc blende. It occurs in fissures and small pockets. There is a good deal of calcite in the joints with the galena, and these joints are mostly vertical. The small amount of zinc blende taken out is reported to have come from the bottom of the shaft. (A. H. Purdue, 1900.)

The Iola mine is in 20 N., 18 W., section 35, south half of the northeast quarter. The rocks are nearly horizontal Ordovician limestones, some of which are brecciated. The developments are all on a branch of Sugar Loaf Creek

which at this place follows a fault that has a downthrow of about 20 feet on the south side. The main development consists of two shafts 90 feet and 45 feet deep respectively, and four small open cuts. The ore consists of galena and zinc blende. The galena is found in thin, vertical sheets in the upper part of the workings, and only a few feet below the saccharoidal sandstone, while the zinc blende is found in brecciated limestone just below the galena. There is also a small amount of smithsonite.

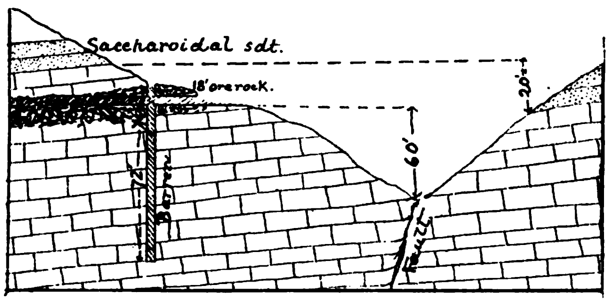


Fig. 22. Section at the Iola shaft.

Besides the openings mentioned there is a tunnel 70 feet in length entering the hill nearly on a level with th mouth of the shaft. This tunnel is in a cavern in limestone, filled with clay. In the open cut at the mouth of the tunnel the dip of the rock is 5 degrees N. 40 degrees W. No ore is found below the upper 18 feet of the 90-foot shaft, but it occurs in all the openings near the creek level. The minerals associated with the ore on this property are calcite and a small account of quartz in very minute crystals. (A. H. Purdue, 1900.)

The White Owl claim is in 20 N., 18 W., section 35, the northwest quarter of the southeast quarter. It is on the hillside 85 feet above the bottom of one of the north-facing valleys that drain into Lower Sugar Loaf Creek. The rocks belong to the Calciferous series, but the St. Joe marble bed crops out on the hill a short distance above the

openings and above that is the Boone chert capping the hills. When this place was visited in January, 1892, the only openings were a cut, 30 by 12 by 8 feet high on the face, and a shallow shaft five or six feet deep. The cut is nearly all in earth. Where hard rock is exposed in the cut and shaft it is a gray dolomite brecciated in place, that is, the overlying and underlying beds are undisturbed. Some of the breccia is very siliceous and where the dolomite fragments have been removed by solution the rock is left very open in texture. Porous fragments of this rock strew the surface of the ground.

There is a second shaft ten feet deep below the open cut, all of it in clay. The ores found at these openings are zinc blende, zinc carbonate and a little galena. The blende shows best on the right side of the open cut, while the zinc carbonate fills cavities and has been left outstanding on some of the rock surfaces by the decay of the fragments between the cracks filled with smithsonite.

The Yankee Boy claim is on the headwaters of the Lower Sugar Loaf in 20 N., 18 W., section 35, the northeast of the southeast quarter. The upper openings are on the north side of Pine Ridge in a narrow valley that opens toward Lead Hill, and are 450 feet above that town. The rocks are horizontal Ordovician dolomites on the lower slopes with St. Joe marble overlying them, and the Boone chert series capping the hills. The ores are both galena and zinc blende. The galena occurs in a more or less decomposed dolomite. A partial analysis was made of the gangue rock which shows it to contain 36.75 per cent. of carbonate of magnesia. Most of the lead comes from an open cut in earth and gravel. One small pit shows a well-defined streak of galena across it. A shaft sunk here in 1891 found both lead and zinc in the solid rock, the lead being in the upper portion. Another open cut 30 by 4 by 5 feet is well down in the Ordovician rocks. Here zinc

blende fills the small crevices in the solid dolomite. The rocks containing lead ore in these openings are all more or less brecciated.

One hundred and fifty feet down the gulch from the upper openings a fine quality of zinc blende is found in brecciated dolomite. An average sample of this zinc blende was analyzed.

Analysis of sphalerite from the Yankee Boy.

Zinc, Zn	65.88
Sulphur, S	31.77
Silica, SiO_2	0.10
Iron, Fe	0.62
Magnesia, Mg	0.14
Calcium, Ca	trace
Cadmium, Cd	trace
	98.51

The Buffalo claim, known also as the *Tallow Clay mine*, is in 20 N., 18 W., section 35, the southwest of the southeast, on the head waters of one of the branches of Lower Sugar Loaf Creek. The mine is high on the side of the great Boone chert plateau that extends from Dodd City westward past Elixir. Our geological notes have nothing upon the age of the rocks exposed in the openings, from which we infer that the evidence of their age was not satisfactory when the place was last visited in January, 1892. The openings, however, are near the dividing line between the Ordovician rocks exposed over the valleys to the north and the Lower Carboniferous beds that crown the hills on all the other sides.

The openings consist of a shaft and two open cuts. The cuts are near the bottom of a gulch, and are in flint and clay, most of it tallow clay. This clay is of various colors: pink, red, yellow specked with white, and striped. It occurs as seams or bands two or three inches thick and from twelve to fifteen feet in length, and separated from each other by gritty bands. The tallow clay from this cut was analyzed with the following results:

Analysis of tallow clay from the Buffalo claim.

Silica, SiO_2	51.03 per cent.
Alumina, Al_2O_3	16.98 per cent.
Zinc oxide, ZnO	14.10 per cent.
Ferric oxide, Fe_2O_3	6.98 per cent.
Ferrous oxide, FeO	0.69 per cent.
Titanic oxide, TiO_2	trace
Lime, CaO	1.16 per cent.
Magnesia, MgO	1.34 per cent.
Potash, K_2O	0.45 per cent.
Water, H_2O	8.88 per cent.
	100.61 per cent.

The zinc oxide in this analysis is equivalent to 11.31 per cent. of metallic zinc.

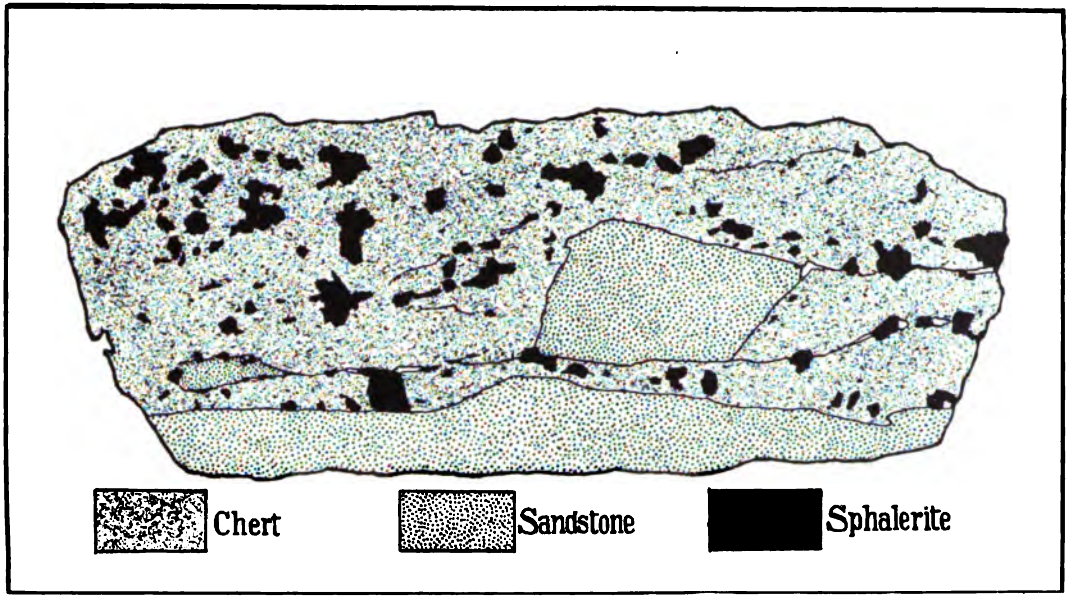
Zinc carbonate and a little malachite are found in this mine.

About thirty feet above the open cut is a shaft 25 feet deep in clay and broken limestone blocks. A little galena was found in this shaft at a depth of twelve feet; at a depth of 13 feet zinc ore was found. The galena was analyzed with the following results:

Analysis of galena from the Buffalo claim.

Lead, Pb	86.02
Sulphur, S	13 80
Silica, SiO_2	trace
Iron, Fe	trace
Antimony, Sb	trace
Silver, Ag	0.00
	99.82

The galena found in the clay was all more or less altered on the outside. An analysis of some of this gray coating showed that the galena had been changed to *pyromorphite,* a lead phosphate.



Chert containing disseminated zinc blende and angular fragments of sandstone from the Markle mine; natural size.

Analysis of pyromorphite coating on galena from the Buffalo claim.

Lead oxide, PbO	71.28
Lime, CaO	6.20
Phosphoric acid, P_2O_5	16.61
Chlorine, Cl	2.25
Carbon dioxide, CO_2	1.74
Silica, SiO_2	0.22
Water, H_2O	0.36
Iron and Alumina, Fe_2O_3; Al_2O_3	0.88
Magnesia, MgO	trace
	99.49

The Markle mine is in 20 N., 17 W., section 31, the northeast of the southwest quarter, about the middle of the two forties, on a branch of Sugar Loaf Creek known as Markle Hollow. The development consists of a shaft 77 feet deep, which is said to have been made through broken limestone and sandstone containing seams of "tallow clay." There is also a tunnel 50 feet long as shown in the accompanying sketch. The ore is chiefly zinc blende, with some

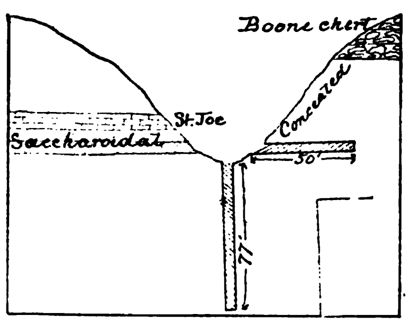


Fig. 28. Section at the Markle mine.

smithsonite, and occurs in the interstices of the brecciated rock on the tunnel level and also disseminated through both the primary and secondary chert; a little galena has also been found in the form of large crystals imbedded in compact gray chert. The relations of the ore to this chert and sandstone are shown in plate IX. It is said that no ore was obtained from the shaft except a small amount of

zinc blende in the bottom. When the place was visited by Professor Purdue in July, 1900, the mine was not in operation and the shaft was almost filled with water. The smaller ravine in which the mine is situated is in a slight fault with the downthrow of about 25 feet on the southeast side. The saccharoidal sandstone is on the south side at the top of the shaft, but the tunnel is in brecciated chert of Ordovician age. This chert is broken into angular fragments, large and small, and there are also angular fragments of clean white sandstone imbedded in the chert, and sometimes the zinc blende is found attached to the clean sandstone. (See Fig. 23.) One fragement of this sandstone observed was 2 feet by 6 inches. The St. Joe marble

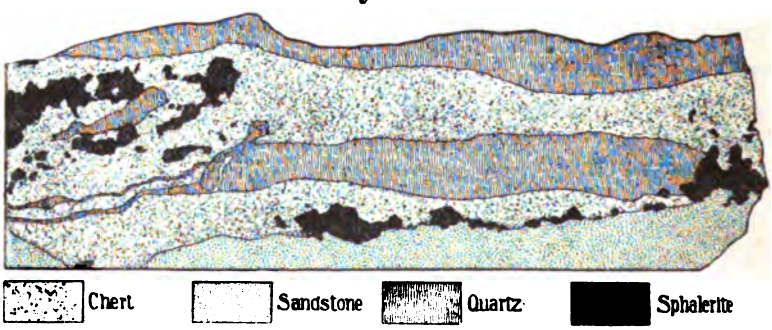


Fig. 24. Sphalerite in chert and sandstone at the Markle mine. (Length of specimen five inches.)

is about 20 feet above the zinc-bearing horizon at the Markle mine. Analyses of two average samples of the sphalerite from this mine show the ore to be remarkably pure.

Analyses of sphalerite from the Markle mine.

Zinc	66.58	66.42 per cent.
Iron	0.44	0.23 per cent.
Silica	0.26	0.29 per cent.
Sulphur	33.54	32.82 per cent.
	100.82	99.76

When this mine was visited in January, 1892, many interesting examples were seen of large crystals of zinc blende almost entirely coated with smithsonite. When

this coating was broken off it was found that it could not be entirely freed from zinc blende because the smithsonite had been formed by the alteration of the blende in place so that small needles of sphalerite were left penetrating the zinc carbonate. This will account for the sulphur found upon analysis of this coating.

Analysis of smithsonite coating sphalerite from the Markle mine.

Zinc oxide, ZnO	63.90
Iron oxide, Fe_2O_3	0.73
Silica, SiO_2	0.86
Sulphur, S	3.57
Carbon dioxide, CO_2	31.73
	100.79

The zinc oxide in this analysis is equivalent to 51.27 per cent. of metallic zinc.

Much tallow clay has been found in seams and pockets in these openings. These deposits are said to be two feet thick in many places. The clays seen here are of a waxy brown and gray color and upon drying split up into thin flakes.

Samples were taken and analyzed with the following results:

Analysis of Tallow Clay from the Markle mine.

Zinc oxide, ZnO	37.54 per cent.
Silica, SiO_2	36.65 per cent.
Alumina, Al_2O_3	10.05 per cent.
Iron, Fe_2O_3	2.86 per cent.
Iron (ferrous), FeO	0.53 per cent.
Lime, CaO	2.20 per cent.
Magnesia, MgO	1.62 per cent.
Soda, Na_2O	0.40 per cent.
Potash, K_2O	0.35 per cent.
Water, H_2O	8.92 per cent.
	101.12 per cent.

Sand in the dried clay, 10.50.

The zinc in this analysis is equivalent to 30.12 per cent of metallic zinc.

Many small examples of aurichalcite and a little chalcopyrite are found at this mine.

A steam crusher and hand jigs have been in operation, and it is reported that 70 or 80 tons of ore have been shipped from this mine, part of it blende and part of it smithsonite. Work first began here in February, 1891.

The Silver Dick shaft is in 20 N., 17 W., section 31, southwest quarter. The development consists of a shaft 30 feet deep in horizontal Ordovician quartzite. Near the bottom is some disseminated ore and a small amount of blende in pockets. The blende of the pockets is of a bluish green color. (A. H. Purdue, 1900.)

Fig. 25. Section at the Silver Dick.

The Pigeon Roost mine is in 20 N., 17 W., section 31, the southeast quarter, at the mouth of Pigeon Roost Hollow. The rocks in which the workings are belong to the Calciferous series of the Ordovician, but the St. Joe marble is exposed on the side of the hill as is shown in the accompanying cut.

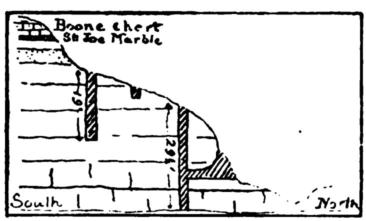


Fig. 26. Section at the Pigeon Roost.

The rocks at the bottom are limestones (dolomites) with chert next above and saccharoidal sandstone above the chert. In places the chert contains cavities left by the

dissolving out of zinc blende crystals. The ores are both zinc blende and zinc silicate, and there is also a little galena in one part of the openings. Fifteen feet west of the main shaft the zinc-bearing rock is exposed in place in a little open pit.

The Pilot Rock mine is on the upper part of Lower Sugar Loaf Creek, in 20 N., 17 W., section 32, south half of the northwest quarter. The openings are in horizontal rocks of Ordovician age about fifty feet below the red St. Joe marble. The development consists of a shaft 75 feet

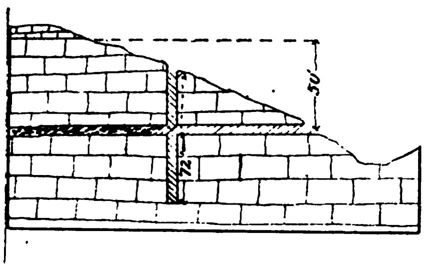


Fig. 27. Section at the Pilot Rock shaft and tunnel.

deep in Ordovician rocks and a tunnel 6 feet by 8 feet in section and 135 feet long. No ore was found in the shaft above the tunnel except a small amount of galena found a few feet from the surface. On the level of the tunnel in the shaft, 10 feet of ore-bearing rock was passed through. The 40 feet of the shaft below the tunnel showed no ore except a very small amount of disseminated blende near the bottom. The tunnel passes through limestone and through chert which is very much decayed, and has mixed with it a good deal of "tallow clay." The clay follows the bedding and appears to have been formed by the decomposition of limestone. The rock is not displaced and is undisturbed, except that the chert is fractured in the usual way. There are occasional small caverns formed by the solution of parts of the rock. The ore is both zinc blende and smithsonite, principally the former. It follows the bedding planes on a level with the tunnel and is mostly free ore.

but there is some disseminated ore in the chert. The ore-bearing rock is a regular bed about 10 feet thick. Ore is frequently found imbedded in the "tallow clay." (A. H. Purdue, 1900.)

The Albert and Jessie mines are in 20 N., 17 W., section 32, the southeast quarter. The St. Joe marble is not exposed at the Albert and Jessie mines, so that the horizon of the ore was not determined at the last visit (July, 1900), but judging from the position of the St. Joe marble at the Pilot Rock, that stratum must be about 50 feet above the Albert and Jessie openings.

Opening No. 1 consists of a shaft 10 feet deep in brecciated flinty limestone. The ore is disseminated zinc blende.

Opening No. 2 is a small open cut 5 feet by 15 feet, 3 feet deep, in cherty limestone. The ore is disseminated zinc blende.

Opening No. 3 is a curbed shaft 20 feet to water; total depth unknown. There is a small amount of zinc blende on the dump.

Opening No. 4 is an old shaft just above the level of the creek. Disseminated zinc blende and iron pyrites in quartzitic rock are found on the dump.

Opening No. 5 is a shaft with its mouth 10 feet above the bed of the creek. There is a small amount of disseminated zinc blende on the dump.

Opening No. 6 is a small open pit in the limestone in the bottom of the creek. The ore is disseminated zinc blende though there is but little of it. (A. H. Purdue, 1900.)

The Major Durham is on a tributary of Sugar Loaf Creek in 20 N., 17 W., section 20, the southwest quarter. The principal opening is a cut 30 feet by 40 feet into the hillside, and 18 feet deep at the inner end. The cut is filled with decomposed chert, which looks very like the

Boone chert, but no fossils were found in it and it is too much decayed to be identified. The floor of the cut is 7 feet below the base of the St. Joe marble. There is no displacement of the marble, however, either north or south of the cut, or on either side of the creek. I account for the chert in this place by the theory of a cavern whose roof of Boone chert has fallen in. After the caving in of the chert the ore was deposited in the interstices of the broken rock where a considerable amount of smithsonite and some hydrozincite is now found associated with calcite and quartz. Thus far no zinc blende has been found. Twenty feet north of the north side of the cut is a shaft 38 feet deep in solid, unbroken, Ordovician limestone. Galena is reported to have been found in the upper part of this shaft, but zinc blende was found only in the bottom six feet with calcite in somewhat brecciated limestone. About 20 tons of smithsonite are on the dump (July, 1900), besides some three or four tons of rock carrying zinc blende, all of the latter having been taken from the shaft. The saccharoidal sandstone seems to be wanting at this place. (A. H. Purdue, 1900.)

The Marble Falls mine is in 20 N., 17 W., section 27, the northwest quarter of the southeast quarter. The openings are in Ordovician limestones about 70 feet below the St. Joe marble. The rocks have a low dip N. 70 degrees E. The development consists of an old shaft near the bank of the creek, and an open cut or quarry in the bed of the creek 20 feet by 12 feet, 4 feet deep. The shaft is said to have produced no ore, but the quarry produces a considerable amount of zinc blende and some smithsonite in brecciated limestone. There are eight to ten tons of ore on the dump. (A. H. Purdue, 1900.)

NOTES ON THE MUSIC CREEK REGION.

The Famous is in 20 N., 17 W., section 24, the southeast of the southwest, and near the head waters of Music Creek. The openings are at or near the base of the St. Joe marble bed of the Lower Carboniferous.

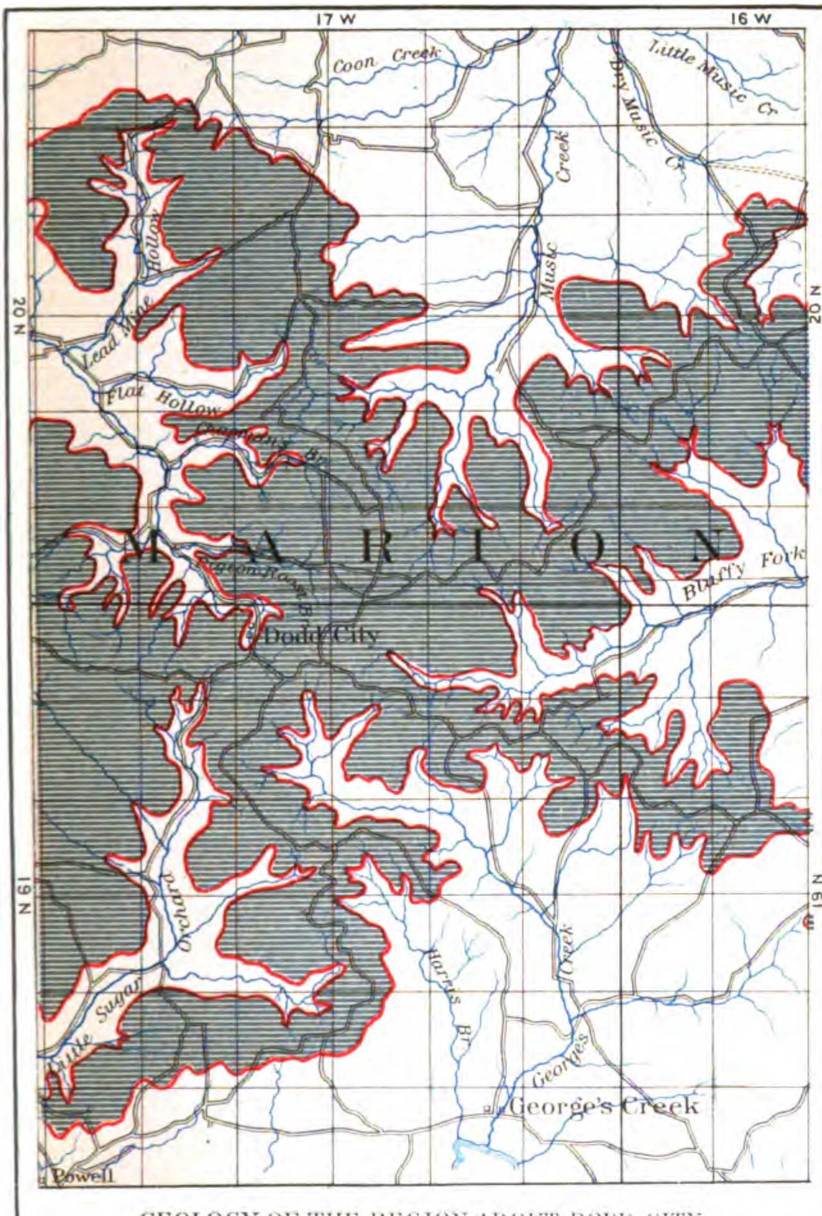
On the north side of the hollow opposite the openings the St. Joe marble rests upon a thin bed of saccharoidal sandstone.

There is a shaft 27 feet deep and an open cut about the mouth of the shaft. The St. Joe bed is here much brecciated and the angular fragments are cemented with chert of a later age. On the rock face above the shaft are small veins of dark-colored smithsonite. A similar blende-bearing breccia with quartzite fragments was found in the bottom of the shaft. Most of the rocks of the shaft are granular like the St. Joe marble. Some of the rocks exposed in the open cut formerly contained abundant crystals of zinc blende; these have been dissolved out and the rock retains the angular cavities from which the zinc has been removed. Some smithsonite is found here and a good deal of calamine. There also occur in these openings beautiful little spherical crystals of *aurichalcite,* a carbonate of zinc and copper. This mineral is found at many of the zinc mines of north Arkansas. It is generally small, not much larger than a pea, but it has a beautiful pale green color and a pearly lustre that attract the attention.

Analysis of aurichalcite from the Famous.

Zinc oxide, ZnO	54.80 per cent.
Copper oxide, CuO	16.87 per cent.
Carbon dioxide, CO_2 and Water H_2O	21.72 per cent.
Silica, SiO_2	5.72 per cent.
Iron oxide, Fe_2O_3	0.48 per cent.
	99.04 per cent.

The zinc oxide in this analysis is equivalent to 43.97 per cent. of metallic zinc.



GEOLOGY OF THE REGION ABOUT DODD CITY.

Scale 1 inch = 2 Miles

JULIUS BIEN & CO. N.Y.

A little chalcopyrite is also found here, but not enough to affect the ore.

Hunt, Malloy & Blevins. This property is on the head waters of Music Creek in 20 N., 16 W., section 18. The openings are in horizontal rocks of Ordovician age, but they are near the contact of the Lower Carboniferous beds with the Calciferous series. The hilltops in the vicinity and 1500 feet southeast of the mines are 365 feet above Music Creek at the upper end of its valley; some loose angular fragments of fossiliferous chert are scattered over them, but there are no exposures on them of Boone chert or of St. Joe marble in place.

This locality is especially favorable for seeing the topographic relations of the Carboniferous rocks to those of Ordovician age. Looking westward one sees on the left a long line of flat-topped hills of Boone chert with a north-facing escarpment; below and to the right are the zinc-bearing Ordovician rocks forming the valley floor of the Music Creek and Coon Creek country and draining northward into White River.

There are four open cuts on this property from which smithsonite and zinc blende have been taken. The rock in which the zinc is found is a highly siliceous one containing magnesia and zinc. This rock was analyzed with the following results:

Analysis of the gangue rock from Hunt, Malloy & Blevins' tract.

Zinc oxide, ZnO	6.20 per cent.
Magnesia, MgO	6.68 per cent.
Iron oxide, Fe_2O_3	0.68 per cent.
Silica, SiO_2	76.00 per cent.
Carbon dioxide, CO_2	10.08 per cent.
	99.54 per cent.

The zinc oxide in this analysis is equivalent to 4.97 per cent. of metallic zinc. The zinc in this analysis comes from the deposition of smithsonite in the very small cavities through the rock.

This rock is in places covered with a thin coating of a reddish brown substance which upon analysis proves to be smithsonite and ferric oxide.

Northeast of the open cuts and near the ranch house is a shaft 65 feet deep, apparently all in earth. An open cut below the shaft found both zinc blende and zinc carbonate. The crystals of blende are often covered with reddish brown or gray coatings of zinc carbonate, some of them an eighth of an inch in thickness. The carbonates occur also as spongy gray and brownish masses. In the process of alteration of zinc blende to zinc carbonate the change sometimes goes on throughout the mass of sphalerite. This is shown in the following analysis of a partly altered specimen of zinc blende from this property:

Analysis of partly altered sphalerite.

Zinc, Zn	58.58
Sulphur, S	20.86
Carbonic acid, H_2CO_3	16.20
Water, H_2O	2.92
Copper, Cu	0.68
Magnesium, MgO	0.10
Iron, Fe	0.20
Cadmium, Cd	trace
Lead, Pb	trace
	100.14

The gangue rock at this place has been much altered in place by the concentration of the silica into thin crinkly bands of small quartz crystals. A little aurichalcite is found among the ores of this property. (Jan. 6, 1892.)

NOTES ON THE JIMMY'S CREEK REGION.

The Mitchell mine is at the head of a ravine draining northward into Jimmy's Creek in 20 N., 15 W., section 30, the northwest quarter. The rocks are horizontal bluish Ordovician limestones, containing many small irregular cavities usually lined with quartz crystals.

Opening No. 1 consists of a cut 30 feet by 40 feet, 6 feet deep. The rock looks very much like that that fur-

nishes the ore at the Big Star. The ore is galena, which occurs in some of the cavities mentioned, and also sparingly in thin sheets along the lamination planes. There is also a very small amount of zinc blende. The ore-bearing rock is about five feet thick.

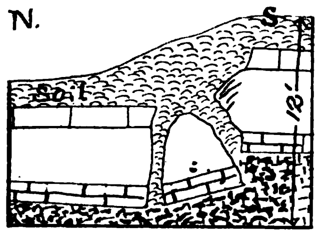


Fig. 28. Section at opening No. 2 of the Mitchell mine.

Opening No. 2 is about 900 feet north of No. 1, at the head of a small ravine leading into Jimmy's Creek, and apparently at the same horizon as opening No. 1. The ore is blende and smithsonite occurring in the fractures of the stone. The development consists of an open cut 45 feet long and 10 feet wide, running east into the hillside, with a face 12 feet high at the back. This cut follows a fault that has a downthrow of three feet on the north side. (A. H. Purdue, 1900.)

The Gregory mine is on a branch of Jimmy's Creek in 20 N., 15 W., section 30, the southwest quarter. The openings are in horizontal Ordovician rocks. The development consists of an open cut on the hillside 20 feet by 20 feet, 7 feet deep at the back, and a 15-foot shaft 60 feet from the quarry and further up the face of the hill. The ore in the quarry is zinc blende in the fissures or brecciated limestone; that in the shaft is smithsonite at the top and zinc blende at the bottom. About 20 tons of ore-bearing rock are on the dump. (A. H. Purdue, 1900.)

The Bull Shoal mine is in 20 N., 15 W., section 31, the southwest quarter. The rocks are Ordovician limestones. There is an open cut in the limestone, ten feet by twelve

feet and four feet deep. Zinc blende and smithsonite occur in fissures in the rock. Thirty feet north of this cut is a second one of equal size, also showing blende and smithsonite in the same manner. (A. H. Purdue, 1900.)

The Big Star mine is on Wild Cat Creek, a branch of Jimmy's Creek, in 20 N., 16 W., section 22, the southeast quarter. The rocks are hard, bluish, Ordovician limestone dipping three or four degrees S. 20 degrees W. This rock is full of small cavities of irregular shape, there being often as many as forty exposed on a square foot. All of these cavities are lined with minute quartz crystals. A few of them contain zinc blende surrounded by the quartz crystals.

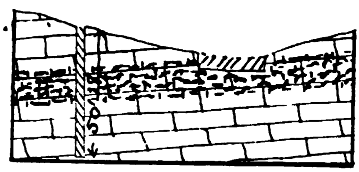


Fig. 29. Section through shaft No. 1 at the Big Star.

Cut No. 1, a quarry or open cut 30 feet by 20, 4 feet deep, exposes four feet of this rock. The bed is said to be 12 feet thick, and it is about 150 feet below the base of the St. Joe marble bed.

Cut No. 2 is also in the bed of the creek 90 feet south of cut No. 1. It is 30 feet by 40 feet, 5 feet deep. It is in the same rock and has the zinc ore occurring in the same manner as in No. 1.

Shaft No. 1 is 50 feet deep and passes through an ore-bearing bed 12 feet thick. The upper portion of this bed is the one exposed in cut No. 1.

Shaft No. 2 is 45 feet deep and passes through the 12-foot ore-bearing stratum penetrated by shaft No. 1. The ore is zinc blende. A steam crusher and jigs have been erected on this property. Five or six tons of ore are sacked ready for shipment. (A. H. Purdue, 1900.)

The Mitchell property on Jimmy's Creek is about 300 feet west of district schoolhouse No. 13, in 20 N., 16 W., section 25, the southwest quarter of the southwest quarter. The rocks are well down in the Ordovician sediments.

The opening is eight feet above the bed of a stream flowing into Jimmy's Creek, and is an open cut about thirty feet long. The rocks in the cut are dolomites brecciated in little pockets but not through the mass of the beds. The ores are zinc carbonate and some zinc blende. Most of the zinc blende crystals seen, however, are thickly encrusted with smithsonite. This opening is considered to be the lowest in the Jimmy's Creek district.

The Lost Bell claim is in 20 N., 16 W., section 35, the northwest of the northwest quarter, about 75 feet higher on the hills than the "Cincinnati." The rocks are dolomites, shales and brecciated magnesia limestones of Ordovician age. The prospect consists of an open cut, 50 feet by 25 feet by 5 feet, in dolomite with a greenish shale-like rock at the bottom of the opening, and a compact gray dolomite beneath. The ores are mostly zinc carbonate, but there is also some zinc blende and a little lead. Some of the smithsonite occurs in the form of reddish brown masses of very small separate crystals that look like masses of mustard seed stuck together. The cubes of galena are occasionally altered on the surface to lead carbonate—cerursite.

The Cincinnati is near Jimmy's Creek in 20 N., 16 W., section 35, the northwest quarter of the northwest quarter. The rocks of this part of the valley of Jimmy's Creek are all horizontal Ordovician sediments. Those in which the ore is found at the Cincinnati are mostly siliceous dolomites. Upon decay the thin ribbons of quartz in these rocks are left outstanding upon the surface.

There is a drift 60 feet long in the hillside. In this there are little pockets or cavities, some of them lined and

others quite filled with galena. Some of these cavities look as though galena had once occupied them, but had been removed in solution. Some of them are now lined with thin film-like coatings of carbonate of lime. These crusts are supposed to be zinc carbonate but chemical analysis was made of some of them and though they do contain a little zinc, the body of the material is carbonate of lime.

There are several open cuts about the mouth of the tunnel; in these cuts galena, zinc blende and zinc carbonate have been found. It is said that 25 tons of lead ore have been shipped from this mine, and there were many tons of smithsonite in the ore bins when the property was visited Jan. 6, 1892. There were also a crushing plant, jigs, boiler engine (30 h. p.), ore bins and other buildings at the mines.

The Blue Flag claim is on the Bluffy Fork of Jimmy's Creek, partly in 20 N., 16 W., section 33, and partly in 19 N., 16 W., section 4, the northwest quarter of the northwest quarter. The same claim was relocated under the name of the *Arkansas Wonder.* The region is one of Ordovician sedimentary rocks only. These rocks are mostly cherts, but there are blocks of sandstone over the surface suggesting the proximity of an overlying bed of it. The rocks exposed in the open cut and stripping, which are the only openings, are cherts somewhat brecciated and carrying disseminated zinc blende. Some of the blende has been removed by solution leaving the rocks filled with cavities. There are also zinc carbonate and zinc silicate exposed over the uncovered rock surfaces. But little of the hard rock has been removed in the openings. A specimen of the zinc silicate from the claim was examined chemically and found to be a remarkably pure calamine without lime or magnesia and carrying only traces of iron. Small quantities of aurichalcite—the green carbonate of copper and zinc are found here. A little tallow clay is also found in the rock cavities.

The High Peak claim is on the south side of Jimmy's Creek, in 20 N., 16 W., section 33, the southeast quarter of the southwest quarter. This claim was not visited, but it is in a region of horizontal Ordovician rocks, chiefly quartzites, cherts and some sandstones. The only ore found here is said to have been galena, which occurs in large lumps in the decomposed rocks. One lump is reported to have weighed more than forty pounds.

The Big Elephant is in 20 N., 16 W., section 30, the southwest of the northeast quarter near the head of a valley draining into the Bluffy Fork of Jimmy's Creek.

The hills that rise above the mines to the east, north and west are the flat-topped hills of Boone chert with the St. Joe marble beneath. The openings are in rocks of both Lower Carboniferous and Ordovician or Lower Silurian ages. The workings consist (Jan. 6, 1892) of three open cuts and a shaft, one above the other on the slope of a south-facing hill.

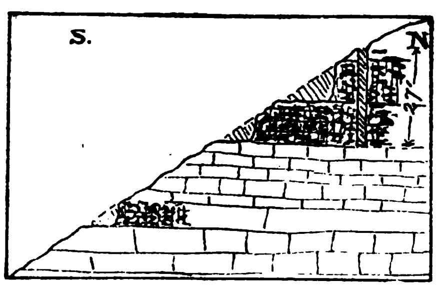


Fig 80. Section through the Big Elephant openings.

While the rocks for the most part are the horizontal undisturbed sedimentary beds so common throughout the zinc and lead region of North Arkansas, there is here a ledge of chert about thirty feet wide that appears to cut across the St. Joe marble and some of the underlying beds. The distribution of the ores is peculiar; the lowest cut yields only zinc, the middle one yields both lead and zinc while the uppermost one yields lead only. The lowest cut

exposes a ten-foot face and the rocks are brecciated quartzite and chert and some dolomite decaying to an apple green color. These rocks, especially the cherts, seem to have been filled with crystals of sphalerite and these have been removed in solution so that the spongy rock is here and there filled with angular smooth-faced cavities preserving perfectly the molds left by the crystals. Zinc carbonate is also found in quantity in this lowest cut.

The middle opening, 12 feet by 12 feet by 8 feet, is 25 feet above the lowest one and in the St. Joe beds or rather at the same horizon as the St. Joe beds. The rock opened upon is much broken, is chert-like and mixed with it is more or less dark red tallow clay. Some of the dolomite is much altered by weathering. In places it has had sharp points of small crystals of dog-tooth spar buried in the rock faces and the removal of the spar has left a deeply pitted surface. A partial analysis of this altered magnesian limestone showed it to have the following composition:

Partial analysis of altered magnesian limestone.

Silica, SiO_2	86.71 per cent.
Zinc, ZnO	2.95 per cent.
Lime, CaO	0.25 per cent.
Magnesia, MgO	0.20 per cent.

The zinc oxide in this analysis is equivalent to 2.36 per cent of metallic zinc.

The remainder of the rock is iron and alumina.

The ores are galena and zinc silicate. The tallow clay from this opening was analyzed with the following results:

Analysis of tallow clay from the middle cut of the Big Elephant (613).

Silica, SiO_2	45.10 per cent.
Alumina, Al_2O_3	16.52 per cent.
Zinc oxide, ZnO	13.98 per cent.
Iron oxide, Fe_2O_3	5.65 per cent.
Iron, ferrous, FeO	3.16 per cent.
Lime, CaO	2.70 per cent.
Magnesia, MgO	1.58 per cent.
Soda, Na_2O	0.62 per cent.
Potash, K_2O	1.15 per cent.
Water, H_2O	10 89 per cent.
	101.30 per cent.

The zinc oxide in this analysis is equivalent to 11.17 per cent. of metallic zinc.

The uppermost open cut is 30 feet long by 15 feet by 12 feet deep at the back. The rock is a yellowish compact chert, somewhat brecciated in places and with lead and zinc disseminated through it. There is but little zinc blende in this rock, however; most of the ore is galena. This galena was analyzed with the results given below:

Partial analysis of galena from the uppermost cut at the Big Elephant (611).

Lead, Pb	84.72
Sulphur, S	13.89
Iron, Fe	0.52
Silica, SiO_2	0.15
Copper, Cu	trace
Silver, Ag	0.00
	98.78

Some of the crystals of galena from this upper cut are coated with cerursite, carbonate of lead.

The shaft is above the uppermost open cut and 50 feet above the lowest cut. It is 27 feet deep and has a clean wall on its east face. Although the shaft is in rocks at the horizon of the St. Joe marble the rocks cut are unlike the St. Joe beds at other places where I have seen them. No ore seems to have been struck in this shaft.

The Full Moon mine is in 19 N., 16 W., section 1, the northeast quarter, and on the divide between Jimmy's Creek and Jenkins' Creek. The rocks are horizontal beds of brecciated Ordovician limestones. Developments consist of five open cuts apparently made many years ago. The rocks are practically barren of soil, and the ore is exposed at the surface. It is chiefly smithsonite, with some blende, all in the joints of the breccia. In the two highest and most easterly openings the smithsonite is especially abundant in the uppermost three feet of the cuts. About 34 tons of rock, rich in smithsonite, are on the dumps at these openings. (A. H. Purdue, 1900.)

The North Star mine is in 19 N., 16 W., section 9, the northern part of the section, and on the north side of Moccasin Fork of Jimmy's Creek, 125 feet above the stream on a steep hillside. The development consists of an open cut 120 feet long and 30 feet wide with a face 10 feet high. The topmost four feet of the rocks of the face is saccharoidal sandstone; the remainder is dolomites and cherts, both of them much decayed. There is a one-foot bed of quartzite at the bottom of the cut. At the west end of the cut rock is taken out with the pick. Except the sandstone at the top, the rock exposed in the face is practically all ore-bearing. The chert bed just below the saccharoidal sandstone cap is full of blende-filled cavities; here and there the blende has been dissolved out. In places this bed is two feet thick, and at the east end of the cut these cavities extend to the lower beds so that the ore-bearing rocks are six feet thick. Interbedded with the decayed portions are streaks of red "tallow clay," some of them three inches thick and six to eight feet long. The ore is mostly smithsonite, much of it remarkably beautiful, but there is some blende and it occurs both in joints formed by rock fractures, where it is associated with dolomite spar, and as dis-

seminated ore, the latter apparently being in much the larger amount.

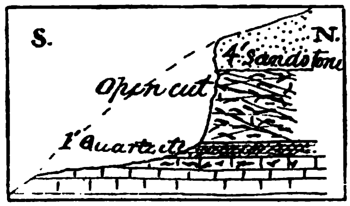


Fig. 31. Section through the North Star cut.

A chemical analysis made of an average specimen of the zinc blende from the North Star mine shows it to be remarkably pure sphalerite.

Analysis of sphalerite from the North Star Mine (607).

Zinc	66.70	per cent.
Iron	0.263	per cent.
Silica	0.00	per cent.
Sulphur	32.987	per cent.
	99.95	per cent.

A pearly botryoidal coating found here proved upon analysis to be smithsonite. The following is one complete and three partial analyses of smithsonite from this mine:

Analyses of smithsonite from the North Star mine.

	No. I	No. II	No. III	No. IV
Zinc oxide, ZnO	61.69	89.03	63.16	56.15
Lime, CaO	2.59			
Iron oxide, Fe_2O_3	0.87			
Carbon dioxide, CO_2, and volatile matter	35.52			
	100.17			

The zinc oxide in these ores is equivalent to the following percentages of metallic zinc in the order given.

	No. I	No. II	No. III	No. IV
Zinc, Zn	49.51	81.32	50.69	45.06

No. II of these analyses had much dolomite mixed with it.

Fifty feet from the east end of the cut is a tunnel, the roof of which is one foot above the floor of the quarry. The tunnel follows the dip of the rock, which is four or five degrees N. 40 degrees W. No ore was found beyond 10 feet from the mouth of the tunnel. The lowest two feet of the tunnel contains a great deal of very white decayed chert. The dip of the rock along the entire face is about the same as that in the tunnel. The horizon of the ore could not be made out, but it is about 175 feet below the top of the hill which consists of Boone chert. There are about 150 tons of rock, very rich in smithsonite, on the ore heap. The development work was done some years ago. Moccasin Fork contains at this point an abundance of water for milling purposes. (A. H. Purdue, 1900, and J. C. Branner, 1892.)

The East Star claim is in 19 N., 16 W., section 9. The rocks of the region are all Ordovician sediments:—sandstones, cherts, quartzites and dolomites. The workings which are on the slope of a hill 150 feet below its summit consist of an open cut 30 by 12 by 6 feet high on the face, and a shaft 18½ feet deep sunk at the end of the cut. Some of the magnesian limestone contains a little disseminated zinc blende, but when examined January 7, 1892, there was not much ore to be seen.

The Big Buffalo is on the drainage basin of Bluffy Fork of Jimmy's Creek in 19 N., 16 W., section 8, the northeast quarter. The rocks are all horizontal Ordovician sediments—quartzites, cherts, and breccias—but the St. Joe marble overlies them in the eastern part of this section while the Boone chert forms the water-shed.

Near the bottom of the gulch is an open cut in chert, some of it brecciated, 30 feet by 15 by 12 feet on the face. The ore is zinc blende disseminated in crystals, some of them the size of a hazel nut through a brecciated chert cemented by a chert of later formation. In some cases the

zinc blende is deposited between thin layers of quartzite. There is likewise some zinc carbonate, both gray and brown, encrusting the rocks and lining the cavities in them.

The Little Buffalo is about 600 feet west and a little south of the Big Buffalo (19 N., 16 W., section 8, northeast quarter). The geology is about the same as that of Big Buffalo, the rocks being Ordovician cherts, quartzites, and dolomites brecciated here and there, but the beds are here slightly folded. Some of the gray cherts are thin-bedded and contain bands of greenish or greenish gray rock that looks somewhat like clay.

The openings are all open cuts or pits: one of these is 20 feet long, 15 feet wide and 12 feet high on the face. At the top of the cut there is two feet of earth, below this a thin-bedded chert and below this is the zinc-bearing chert down to the bottom of the cut. From some of the chert the zinc blende has been dissolved, leaving the characteristic angular cavities, but there is much blende still thickly disseminated through the gangue rock.

Another opening on the north side of the gulch exposes four feet of limestone at the top with a cherty zinc-bearing bed beneath it, the zinc blende being disseminated. This rock is not brecciated but is thick-bedded and its horizontality is not disturbed. Both the rocks and ores have been considerably altered since they were originally deposited. The ores occur here as sphalerite, calamine, and as various forms of smithsonite. The brown zinc carbonate found here is especially noteworthy; it occurs in the form of compact crusts with its exposed faces covered with small globular crystals of smithsonite that cling together in little strings resembling the rootlets of plants. A partial analysis of this brown carbonate shows that it contains 48.99 per cent. of metallic zinc.

The abundant cavities in the rocks are lined with either calamine or smithsonite, and wherever crystals of zinc blende have been long exposed in a crevice or opening they are covered with coatings of smithsonite—some of it gray, some of it a light brown color. Partial analysis of some of this smithsonite with some of the gangue rock shows it to contain the equivalent of 49.95 per cent. of metallic zinc. Partial analysis of the zinc blende shows it to contain the equivalent of 44.9 per cent. of metallic zinc. In many cases the smithsonite is coated over with calamine. The mineral aurichalcite—the carbonate of zinc and copper—is found in some of the open pockets made by the removal in solution of zinc blende crystals.

The Barnes mines are on the head waters of Jimmy's Creek in 19 N., 17 W., section 1, the northeast quarter of the southwest quarter. The openings are all in Ordovician rocks.

Opening No. 1 is a shaft 24 feet deep, starting about 100 feet below the St. Joe marble. At the depth of 18 feet a small amount of zinc blende was found in pockets in compact bluish-gray limestone. This rock contains a large number of cavities an inch or more in diameter, apparently formed by solution; a small number of them contain zinc ore, a little iron pyrites, and calcite.

Opening No. 2 is at the creek level. Two or three shots fired in the rock at this point disclosed zinc blende in veins in the brecciated limestone.

Opening No. 3 is 225 feet N. 70 degrees east of opening No. 2. It is an open cut 18 feet in length along the face of the cliff, extending into the hill 10 feet and 8 feet deep at the back. The rock is much broken but a dip of about 7 degrees N. 20 degrees W. is perceptible. The bottom four feet of the cut is in quartzite, the upper four feet is in limestone. The ore is chiefly zinc blende, but there is also some smithsonite. It occurs in the fractures of both

the quartzite and the limestone. Zinc blende occurs at two places in the horizontal strata of limestone in the bed of the creek between openings 2 and 3.

Opening No. 4 is a shaft on the west bank of the creek 18 feet deep and 300 feet S. 70 degrees W. from opening No. 2. Zinc blende was struck in good quantity at a depth of 12 feet, where a four-foot bed of fairly rich brecciated limestone was found. A small amount of galena was found near the top of the shaft. The rock is limestone, much fractured all the way down. No general dip can be made out, but just south of the shaft in the creek it is 7 degrees S., 50 degrees W. (A. H. Purdue, 1900.)

The Beatty mine is in Bluffy Fork of Jimmy's Creek in 19 N., 17 W., section 1, the southeast quarter of the southwest quarter. The rocks exposed are slightly folded Ordovician dolomites. The ore is zinc blende almost exclusively, and is found with a little calcite in the joints and cavities of the dark dolomite and in veinlets from a quarter of an inch to four inches in thickness. Beautiful examples of the filling of rock fractures with zinc blende are to

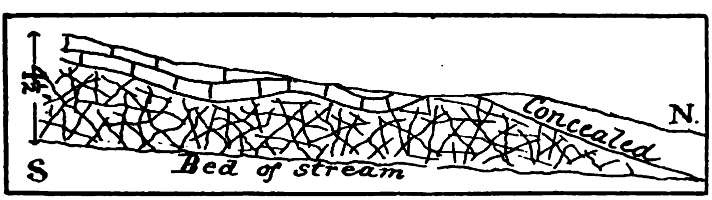


Fig. 22. Section at the Beatty showing the breccia and the disturbed overlaying beds.

be seen here. The development consists of the diversion of the stream from its former channel and of a trench cut along this old channel for a distance of about two hundred feet. Brecciated siliceous dolomite is exposed for 100 feet along this trench. The thickness of the ore-bearing bed is not apparent; it is exposed for only four feet at most. A gentle synclinal fold carries the zinc-bearing bed out of sight, but 150 feet down-stream it appears at the surface

again. A small pit from three to four feet deep has been sunk on the ore bed [illegible] attempt seems to have been made to determine the thickness or extent of the ore-bearing bed.

Fig. 33. General section along the creek bed at the Beatty.

The ore-bearing rock so far as exposed all seems to be workable. The low anticline exposed bears about N. 40 degrees W. A small amount of galena has been taken out on this property; some zinc blende was found directly associated with the galena. The property is said not to have been worked since 1890. There was formerly a steam crushing plant here; the ore was concentrated by hand jigs. The crusher is now at the Markle mine. It is said that 80 tons of clean zinc ore were shipped from this mine in 1891.

NOTES ON THE GEORGE'S CREEK REGION.

The Clear Jack mine is on a branch of George's Creek in 19 N., 17 W., section 11, the southeast quarter. The rocks penetrated are horizontal Ordovician brecciated sandstones and dolomites. The principal development is a shaft 77 feet deep located 250 yards S. 30 degrees E. from shaft No. 2 of the Bear Hill mines. Two ore-bearing beds are cut by this shaft: one bed four feet thick at a depth of 20 feet in calcareous sandstone; a second bed ten feet thick, beginning at a depth of 55 and continuing to 65 feet in a dark gray, fine-grained, brecciated sandstone. The ore is zinc blende associated with calcite in the breccia. The upper bed contains a little iron pyrites. Opening No. 2 is 150 yards N. 20 degrees E. from the shaft, and is about 15 feet higher. It is an open cut in the hillside 20 feet by 10 feet, 6 feet deep, and is in a clay-filled cavern in Ordovician limestone. The ore is both zinc blende and smithsonite,

and occurs in dolomite fragments imbedded in the clay. About two tons of ore-bearing rock are on the dump. No ore has been found in the walls of the cavern. (A. H. Purdue, 1903.)

The old "Wood" mine has not been examined by the writer or his assistants, but the following notes upon it are taken from Owen's report published in 1858.* This property is in 19 N., 17 W., section 13 on the upper part of George's Creek. The rocks are the horizontal Calciferous beds and consist chiefly of dolomites. An analysis was made of the rock carrying the ore.

Analysis of the gangue rock from the old Wood mine.

Silica with a trace of clay	8.191 per cent.
Alumina with a trace of iron	3.028 per cent.
Carbonate of lime	50.041 per cent.
Carbonate of magnesia	43.317 per cent.
Carbonate of zinc	1.950 per cent.
Potassa with trace of soda	0.485 per cent.
	100.957 per cent.

Owen speaks of this locality as "The richest and best "locality of these zinc ores that have yet been examined in "this country. * * * The surface indications here are "quite encouraging and lead to the inference that consid- "erable bodies of both the carbonate and sulphuret of zinc "exist more deeply seated in the crevices of the rock; "indeed, these ores seem to occur here in veins between "well-defined walls of rock, the main vein running north "30 degrees east. * * * I would particularly designate "this place as worthy of the attention and exploration of "the zinc manufacturer, as the locality gives promise, as "far as can be judged from the partial openings made, of "affording good rich zinc ores in sufficient quantities to "supply a furnace.

* First report of a geological reconnoissance, etc. By D. D. Owen, pp. 55 and 151-155. Little Rock, 1858.

"There is more sulphuret of zinc at these than at the "zinc mines of Lawrence County; but still there are large "quantities of carbonate also, which yield from 48 to 52 "per cent. of zinc."

Analysis of brownish white smithsonite from Wood's mine.

Clay, sand and silica	7.523 per cent.
Oxide of zinc	59.770 per cent.
Peroxide of iron and traces of manganese	3.507 per cent.
Oxide of cadmium	0.486 per cent.
Oxide of lead	0.066 per cent.
Oxide of copper	trace
Lime	0.466 per cent.
Magnesia	trace
Carbonic acid, water and loss	28.182 per cent.
	100.000 per cent.

The zinc oxide is equivalent to 47.97 per cent. of metallic zinc.

Lead was also found at the old Wood mine. Analysis showed this lead to contain 1.67 ounces of silver to the ton of galena.

The Bear Hill mine is in 19 N., 17 W., section 10 (or 11), the northeast quarter of the southwest quarter, on a tributary of George's Creek. The property was examined in January, 1892, and was visited again by Professor Purdue in July, 1900. The openings are in nearly horizontal Ordovician rocks, but the St. Joe marble is only 40 feet (an. bar.) above the mouth of the main shaft, while Boone chert caps the hilltops to the north for several miles. The rocks penetrated are chiefly dolomites and quartzites, somewhat brecciated, and partly decomposed cherts. The cherty rock is very like that common in the zinc mines of this region, and here it contains cavities left by the removal in solution of zinc blende crystals.

When the mines were first opened some smithsonite was found in the upper workings near the surface, but of late only zinc blende has been found in quantity, and this is mostly in a slightly brecciated dark gray dolomite asso-

ciated with calcite. An analysis of an average specimen of zinc blende from the breccia of this mine was made with the following results:

Analysis of sphalerite from the Bear Hill mines.

Zinc, Zn	66.46 per cent.
Sulphur, S	32.30 per cent.
Silica, SiO_2	0.25 per cent.
Iron, Fe	0.15 per cent.
Magnesia, Mg	0.20 per cent.
Calcium, Ca	0.51 per cent.
Cadmium, Cd	trace
	99.87

In the east drift, zinc blende was found extending into both the roof and floor. This ore seemed disposed to run in vertical streaks, one of which was twenty inches wide. In the west drift the dark gray dolomites are slightly brecciated and there is a gentle dip toward the southeast. The ore is zinc blende in streaks and gashes and filling crevices. Professor Purdue visited this place in July, 1900, and wrote of it as follows:

Unfortunately the superintendent was away and the shaft and ore bins were locked, so that a personal examination of neither the shaft nor the ore could be made. The following information was gathered from persons familiar with the workings. The shaft is 157 feet deep. Five drifts run from the shaft, four of which run, respectively, north, south, east, and west; the fifth runs northeast. Ore was found in all these drifts, but the one running northeast is the richest. This is at the 135-foot level. The others are at about the 70-foot level. From the 70-foot level to the 135-foot level the rock is reported to be ore-bearing. No displacement of the rock is apparent at the mine. An old tunnel said to have been 40 feet long runs eastward into the hill at the top of the shaft. In July, 1900, this tunnel was caved in so as to be inaccessible. Shaft No. 2 is from 35 to 40 feet deep. The top of the shaft is about 40

feet below the top of shaft No. 1. Zinc blende both dessem-inated and in the form of veins was found in the uppermost ten feet of the shaft, but no ore was found below that point.

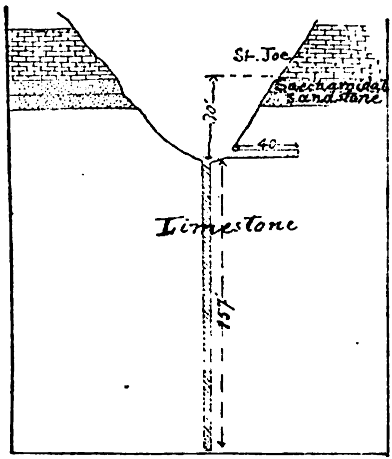
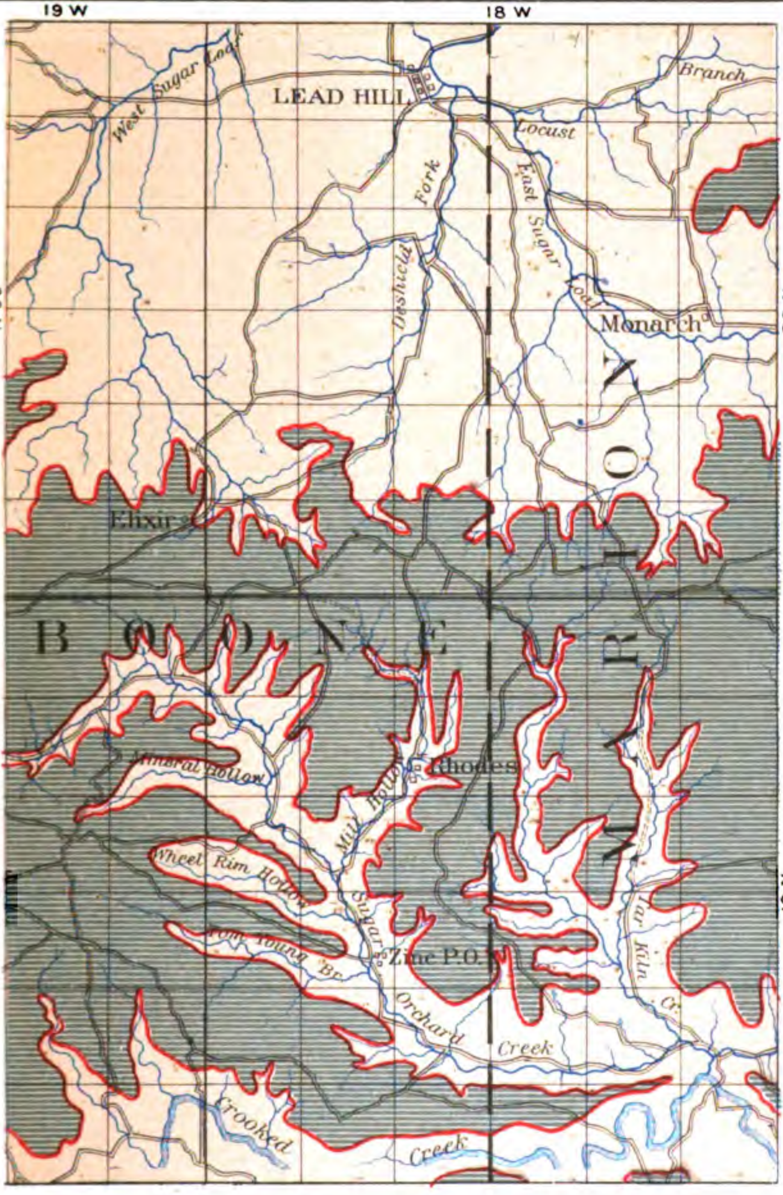


Fig. 84. Section at the Bear Hill shaft.

There is a steam crusher and hoist and one hand jig at these mines, and it is said that 100 tons of ore were shipped a year ago.

NOTES ON THE SUGAR ORCHARD REGION.

It is impossible to mention in detail all the prospect pits or other openings that have been made along Sugar Orchard Creek and its tributaries. Those here spoken of were visited under the kind guidance of various persons more or less acquainted with the region. In its main features the geology of the Sugar Orchard district is quite simple: the horizontal Calciferous rocks which yield the zinc are overlain by the St. Joe marble bed, and above the St. Joe the Boone chert caps the hills on both sides of the streams. But there appear to be local variations in the beds in the vicinity of Coon Hollow, and just here the structure is obscured by deep decomposition. Here, too,



GEOLOGY OF THE SUGAR ORCHARD DISTRICT.

Scale: 1 inch = 2 Miles

0 ¼ ½ ¾ 1 2 3 4 5 MILES

0 1 2 3 4 5 6 7 8 KILOMETRES

JULIUS BIEN & CO. N.Y.

are the interesting zinc blende deposits of the Rosin Jack claim, the widespread deposits of calamine and the considerable pockets or beds of tallow clay. The geology over an area of two or three square miles in that neighborhood is worthy of more attention than it has been possible under the circumstances to bestow upon it.

The Golden City shaft is on Little Sugar Orchard Creek in 19 N., 17 W., section 8, south half of the southwest quarter. The shaft is 70 feet deep and is in horizontal Ordovician rocks. There was no ore above the depth of 65 feet; below that point there is a small amount

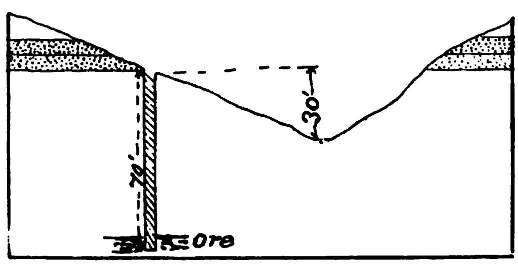


Fig. 25. Section at the Golden City shaft.

of zinc blende in veins in sandstone, limestone and chert. The ore-bearing rock carries a small amount of iron pyrites which is chiefly in small veins along the lamination planes. (A. H. Purdue, 1900.)

The Governor Eagle mine is in 19 N., 17 W., section 7, southeast of the northwest quarter, on a small branch of Sugar Orchard Creek. The rocks are horizontal Ordovician dolomites. The development consists of two shafts 19 and 27 feet deep, starting about twelve feet above the stream bed. It is reported that in the shallower shaft ore was found in greater or less quantities all the way from the surface down. In the deeper one ore was found only near the bottom. The ore is almost wholly zinc blende, but there is also a small amount of smithsonite both as gray smithsonite and the yellow "turkey fat." The ore is

in cavities and joints in coarsely brecciated dolomite and also in thin seams an inch or so in width along the lamination planes. Pink dolomite spar often accompanies the

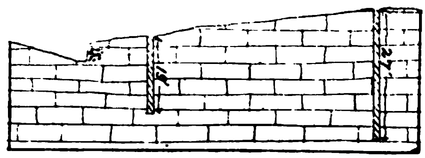


Fig. 36. Section at the Governor Eagle shafts and cut.

blende. The ore is exposed in horizontal veins three inches thick in the creek-bed, fifteen feet below the top of the shallower shaft. The rock is not much displaced but is more or less fractured, furnishing cavities for the ore. An old shaft 10 feet deep and 150 feet up the creek from the recent one yielded a small amount of smithsonite. (A. H. Purdue, 1900.)

Some of the zinc blende from this property is remarkably pure as is shown by one of the following analyses:

Analyses of sphalerite from the Governor Eagle mine.

	(609)	(626)	(663)	(674)
Zinc, Zn	66.69	64.48	60.08	65.09
Sulphnr, S	33.20	32.16		
Iron, Fe	0.67	0.26		
Silica	0.00	1.88		
Calcium	0 00	0.76		
Cadmium	0.00	trace		
	100.56	99.54		

Smithsonite is not abundant at the Governor Eagle but a sample found encrusting zinc blende gave the following:

Analysis of smithsonite encrusting sphalerite, Governor Eagle mine.

Zinc oxide, ZnO	51.44
Zinc sulphide, ZnS	5.04
Iron oxide, $Fe_2 O_3$	3.88
Copper sulphide, CuS	2.96
Magnesia, MgO	1.30
Silica, SiO_2	2.71
Carbon dioxide, CO_2	32.50
Manganese	trace
Antimony	trace
	99.83

The zinc oxide of this analysis is equivalent to 41.28 per cent. of metallic zinc.

The zinc sulphide in this analysis comes from the incomplete alteration to carbonate of the sulphide crystals. In places the saddle-shaped crystals of dolomite spar have been coated with smithsonite and in some instances the dolomite crystals have been removed in solution, leaving cavities in the smithsonite. A partial analysis was likewise made of the gangue rock at these mines.

Analysis of the gangue rock of the Governor Eagle mine.

Carbonate of magnesia, $MgCO_3$	24.02
Carbonate of lime, $CaCO_3$	32.25

The gangue rock is therefore a dolomite. Other chemical examinations show that the gangue rock is in places highly siliceous, and that there is no zinc distributed through its mass.

Small crystals of aurichalcite are common in the partly altered lumps of zinc blende.

The Great Eastern is in 19 N., 17 W., section 17, the northwest quarter of the southwest quarter, and section 18, the southeast quarter of the northeast quarter; the mine is on the latter tract.

Opening 1. There is a small opening, 10 feet by 12 feet, 4 feet deep, on the hillside fifteen feet above a branch of Little Sugar Orchard Creek. The rock is saccharoidal

sandstone of Ordovician age, much fractured, with zinc blende in the cracks. This is the only place at which zinc ore was found in the saccharoidal sandstone.

Opening 2 is upstream three hundred feet northwest of No. 1. A shaft 28 feet deep has dolomite and tallow clay in alternate layers. The ore is both smithsonite and zinc blende, chiefly smithsonite from the clay beds. Some of the carbonate is of a light brown color. There is a small amount of smithsonite near the surface in what appears to be saccharoidal sandstone. Below this no more ore was found till the bottom of the shaft was reached. The ore on the dump said to have come from the bottom of the shaft is rich in smithsonite which occurs in brecciated sandstone.

Opening 3 is on the hillside six feet above the creek level and 150 feet north of No. 2. This is an open cut 12 feet by 18 feet, 5 feet deep. The rick is Calciferous quartzitic sandstone, much brecciated. The ore is chiefly smithsonite, which occurs in the breccia, but there is aslo a small amount of zinc blende. The smithsonite occurs partly as a brown crust. Upon analysis this brown material was found to contain 74.05 per cent. of zinc carbonate, which is equivalent to 38.51 per cent. of metallic zinc. The brown coloring is produced by iron oxide. Some of the carbonate also resembles a coarse sandstone, the mineral being in the form of round grains about the size of a pin head.

The Lemon and Layton prospect is in 19 N., 17 W., section 17, northwest quarter, on the east bank of Little Sugar Orchard Creek. Zinc blende is exposed at and below water level on this stream. The rock is Ordovician limestone and dirps about 70 degrees north 40 degrees west. The ore is in veins in the limestone. The development consists of a small cut on the bottom of the creek, which at the time of the last visit (July, 1900) was filled

with stream deposits. There was not enough of the ore exposed to show whether it was confined to any one bed of rock. (A. H. Purdue, 1900.)

The Hiawatha claim is on Little Sugar Orchard Creek in 19 N., 17 W., section 17, the northwest quarter. The openings are in Calciferous rocks near the top of the series. The overlying St. Joe and Boone chert beds are near at hand in the hilltops north and west of the mines. There is an open cut 20 feet by 10 feet on the east side and 10 feet above Little Sugar Orchard Creek. The rock is dolomite, some of it very much weathered and somewhat brecciated quartzite, containing zinc blende and calcite, and also a little lead ore in the crevices.

There is a second open cut 400 feet south of that just mentioned. This cut is in dolomite somewhat brecciated, with sandstone at the top of the opening. The quarry is 12 feet by 20 feet by 5 feet, and the ore is free zinc blende exposed in the bottom.

An analysis of the gangue rock of this opening shows it to contain 37.21 per cent. of magnesium carbonate and 49.89 per cent. of lime carbonate, hence it is a dolomite. Analysis was likewise made of the zinc blende from this cut.

Analysis of sphalerite from the Hiawatha. (624.)

Zinc, Zn	66.27 per cent.
Sulphur, S	32.58 per cent.
Iron, Fe	0.89 per cent.
Silica, SiO_2	0.21 per cent.
Calcium, Ca	trace
Magnesium, Mg	trace
	99.40 per cent.

On the west side of the creek and about half way between the two open cuts a shaft was started, and was 6 feet deep when the property was examined (Jan., 1892). Some galena was found in small cavities in the dolomites.

The Post Boy is in Coker Hollow in 19 N., 18 W., section 15, the northwest quarter of the southwest quarter and close to the 16th section line. The opening is in the upper part of the St. Joe beds and is about 50 feet by 15 feet by 4 to 8 feet.

The rocks are dolomites, altered siliceous rocks and cherts, and are checked by veins of calcite. The zinc occurs as blende disseminated through beds of quartzite and chert, as calamine, and tallow clay, but in January, 1892, no great amount of ore had been found. The angular cavities in some of the weathered rock show that zinc blende has been dissolved from them, and some of these cavities have been refilled with calamine. The calamine lines most of the small cavities in the rock containing the blende and it was found upon analysis to be generally disseminated through the spongy siliceous cream-colored rock. In a small opening above the cut these cavities are especially abundant and well preserved. Some of the cavities are more than an inch in diameter and the impressions of their faces are perfectly preserved in the compact cherty quartzite. Impressions were taken of some of these cavities and their angles measured; they were found to correspond with the crystalline forms of sphalerite or zinc blende. The St. Joe beds crop out below the opening. The dark red tallow clay from this opening was analyzed with the following results:

Analysis of tallow clay from the Post Boy. (632.)

Silica, SiO_2	40.91 per cent.
Alumina, Al_2O_3	9.33 per cent.
Zinc oxide, ZnO	34.79 per cent.
Ferric oxide, Fe_2O_3	2.25 per cent.
Ferrous oxide, FeO	0.52 per cent.
Lime, CaO	3.42 per cent.
Magnesia, MgO	0.48 per cent.
Soda, Na_2O	0.42 per cent.
Combined water, H_2O	9.02 per cent.
	101.14 per cent.
Water in clay dried at 115° C	9.77 per cent.
Sand in air dried clay	6.62 per cent.

The zinc oxide of this analysis is equivalent to 27.91 per cent. of metallic zinc.

The Legal Tender mines are on the east side of the west branch of Tar Kiln Creek in 19 N., 18 W., section 10, the southwest of the southeast quarter. The general geology is that so common in this part of the zinc regions, namely, horizontal Ordovician rocks in the bottoms of the narrow valleys, St. Joe marble of the Lower Carboniferous overlying the Ordovician, and the Boone chert over the St. Joe.

The Ordovician beds in which the zinc occurs here are cream-colored, spongy, siliceous rocks that look as if they had originally contained a good deal of lime or dolomite but are altered by its removal and left with a spongy open texture. The following analysis shows its composition:

Analysis of the gangue rock of the Legal Tender mines.

By D. P. Mitchell.

Silica, SiO_2	95.793 per cent.
Iron, Fe_2O_3	0.053 per cent.
Alumina, Al_2O_3	2.554 per cent.
Magnesia, MgO	0.429 per cent.
Soda, Na_2O	0.884 per cent.
Water, H_2O	0 688 per cent.
	100.395 per cent.

This rock has imbedded in it angular fragments of chert, and the zinc blende is in pockets in this same bed.

In places the gangue rock is very spongy and its cavities have been almost completely filled with calamine—forming a beautiful silicate ore. A partial analysis of a piece of this silicate-filled rock showed it to contain the equivalent of 45.36 per cent. of metallic zinc.

The openings, when the property was seen in January, 1892, consisted of an open cut and a shaft 15 feet deep. The rock in the shaft was more or less broken and contained clay seams yielding zinc silicate. Where the

rock has been rendered spongy or open-textured by the removal in solution of some of its constituents the microscopic cavities have been partly or completely filled with calamine, so that analyses of any of this spongy rock shows it to contain much zinc, although the presence of the zinc would not be suspected without the analysis.

On the southwest corner of this quarter section a prospect pit exposes zinc blende in beds above the St. Joe marble.

Another claim immediately east of the Legal Tender has been developed by an open cut 10 feet wide and with a 15 foot face. On this face the rocks contain some pockets of beautiful zinc carbonate. This exposure is opposite the St. Joe marble, which is exposed further down the gorge. One sample of zinc carbonate from Major Weaver's claim in the southwest quarter of the southeast quarter of section 10 was analyzed with the following results:

Analysis of smithsonite from Major R. B. Weaver's claim.
(19 N., 18 W., section 10, S. W. of S. E.)

Zinc oxide, ZnO	62.20 per cent.
Carbonic acid, CO_2	33.96 per cent.
Water, H_2O	2.30 per cent.
Silica, SiO_2	0.02 per cent.
Magnesia, MgO	0.18 per cent.
Lime, CaO	1.25 per cent.
Iron and Alumina, Fe_2O_3; Al_2O_3	0.21 per cent.
Cadmium oxide, CdO	trace
	100.02 per cent.

The zinc oxide in this carbonate is equivalent to 49.91 per cent. of metallic zinc.

A claim on the west side of Tar Kiln Hollow, just south of the *Legal Tender* (in 19 N., 18 W., section 15, the northwest quarter of the northeast quarter) has an open cut 25 feet across and 15 feet deep *above* the St. Joe marble. At the top of this pit is a flat rock covered with a thin coat of zinc carbonate. In the upper part of the cut the

rock is chert. Where it is fresh this rock contains disseminated crystals of zinc blende, but where it is weathered, this blende has been removed in solution, leaving the rock quite spongy. Some of the cavities have been refilled with zinc carbonate.

A part of the smithsonite found in the open pit has the clear yellow color given it by cadmium. In the pit there is some tallow clay.

The Rhodes property is mostly deeded land covering a large area about the head waters of Sugar Orchard Creek. One prospect on this land was examined and is mentioned below while others are spoken of under the head of claims, prospects and mines of the Sugar Orchard district. A glance at the map will give one a clear idea of the general geology. The Ordovician rocks are exposed in the bottoms of the valleys and deeper gulches while the St. Joe marble crops out on the slopes generally well up toward the top, and the Boone chert overlies the marble bed and caps the hills. Most of the zinc is found in the upper portion of the Ordovician series.

In 19 N., 18 W., section 16, the southwest of the northwest and bearing S. 70 degrees E. from Mr. Almy's house, gray and dark—almost black—brecciated dolomite carrying zinc blende in the fractures is exposed in the bed of a small stream. There is a little zinc carbonate here and there through the more weathered portion of the ore body. Just below the outcrop of the zinc-bearing breccia hard quartzite is exposed in the stream bed.

From where it is uncovered in the stream the breccia has been opened upon for 100 feet westward along the side of the hill. It retains its general character along this exposure, though there is less zinc as it leaves the bed of the stream. There is some dolomite spar associated with the zinc blende. These rocks have a local, and, for this region, rather sharp dip of 15 degrees to the southeast.

A partial analysis was made of the zinc blende from this prospect which showed it to contain the equivalent of 66.64 per cent. of metallic zinc. The gangue rock was also examined and found to be a siliceous dolomite.

The Rosin Jack is near Mr. Almy's house on Saw Mill Hollow or Mill Branch of Sugar Orchard Creek, in 19 N., 18 W., section 16, the northwest quarter.

The saccharoidal sandstone here rests upon a compact blue limestone that closely resembles the Izard limestone in Izard and Independence counties. It will be seen that the zinc is found in the calciferous series below the St. Joe bed. The ore is a fine quality of zinc blende in brecciated quartzite and dolomite.

This is one of the most interesting looking properties in the Sugar Orchard district, and deserves careful prospecting.

The Kansas claim is in what is known as Dry Hollow near the upper end of the Mill Branch of Sugar Orchard Creek in 19 N., 18 W., section 17, the northeast quarter of the northeast quarter. Here Mill Branch has cut a narrow trench-like valley through the horizontal beds of Boone chert and St. Joe marble into the Calciferous part of the Ordovician rocks. Dry Hollow is a small hollow opening into the Mill Branch valley at the northeast corner of section 17. On the west side of Dry Hollow chert and quartzite are found in the same bed of rock. The openings on the Kansas claim are on the east side of the hollow near the contact between the Lower Carboniferous and the Calciferous beds. The work that had been done when the place was examined in 1892 consisted of strippings or open cuts in sandstones, quartzites and cherts—some of them greatly altered by weathering. But little of the solid rock has been blasted out, however. In many places the rock has contained much zinc blende and this has been removed in solution leaving angular cavities, while the ore found

is nearly all in the form of almost black to white zinc silicate sometimes in streaks a foot wide. The abundance of the zinc silicate is the most striking feature of this property. There is also a good deal of pink and white tallow clay in these openings. A sample of the light colored tallow clay was analyzed with the results given below.

Analysis of tallow clay from the Kansas claim. (634.)

Silica, SiO_2	41.67
Zinc oxide, ZnO	35.88
Alumina, Al_2O_3	8.47
Ferric oxide, Fe_2O_3	2.35
Ferrous oxide, FeO	0 33
Lime, CaO	1.36
Magnesia, MgO	0 51
Soda, Na_2O	0.07
Potash. K_2O	0.57
Water, H_2O	8.28
	99.49
Water in air dried clay at 115° C	8.64
Sand in air dried clay	14.46

The zinc oxide in this analysis is equivalent to 28.79 per cent. of metallic zinc.

A partial analysis of another sample of tallow clay from this same claim showed it to contain 33.32 per cent. of zinc oxide, which is equivalent to 26.73 per cent. of metallic zinc.

The Chicago claim is in 19 N., 18 W., section 17, partly on the east half of the northeast quarter. The openings are strippings, an open cut 30 feet long by 15 feet wide and with a 10-foot face, and a shallow shaft, all in the Calciferous series.

In the bottom of the shaft is much lemon-colored clay. A qualitative analysis (685) of this clay showed it to contain much silica, alumina and oxide of zinc, and a little lime, magnesia and iron. This lemon-colored clay is filled with pockets of red tallow clay. The rock that looks so much like limestone was chemically examined and found to be a dolomite.

The dolomites shown in the accompanying section are cut by streaks of a dark brown rock locally known as "ginger-bread rock," from three inches to four feet in thickness. In these streaks are bands of zinc blende coated with zinc carbonate. Some of the cherts at this opening show that they have contained disseminated zinc blende and that this blende has been removed in solution, leaving the rock full of small angular cavities. Most of the ore is calamine, which sometimes occurs in the form of beautiful stalactites, sometimes filling cracks in the laminated chert, and sometimes filling the cavities left by the removal of the zinc blende from the chert. There are also fine carbonate ores found here.

The Frisco placer is in 19 N., 18 W., section 17, the northwest quarter of the southeast quarter. Some of the openings are on the hill 45 feet above the level of the road at the mouth of Coon Hollow. The rocks are dolomites, quartzites, cherts and breccias, and belong to the Calciferous group; the Boone chert caps the hills a short distance to the north of the openings. The St. Joe marble horizon is about 100 feet above the level of the creek near the mines.

These openings are strippings or irrgular open cuts. One of them is 10 feet high in the back, 30 feet wide and 70 feet long. Here the ore is mostly zinc blende, but there is also much zinc carbonate, silicate and tallow clay in and associated with chert and dolomite, some of it brecciated, much of it altered by decomposition. The overlying beds are quartzites, and still higher up they are laminated cherts from which crystals of zinc blende have been removed in solution. In some cases the cavities left by the solution of zinc blende have been filled with calamine. In the open cut the ores are in horizontal streaks and in the main follow the horizontal beds. The tallow clay occurs in crevices of all shapes.

About 100 feet south of the cut above mentioned and three feet below it is another about 30 feet long and 10 feet deep at the inner end. The rocks are brecciated dolomites and quartzites. Tallow clay of various colors—red, pink, yellow and white—and in abundance was found in this cut. It occurs in streaks, some of which are as much as 4 feet thick.

Other openings upon this claim are on the west side of Coon Hollow and near the bottom of the hollow. At the upper one of these the rock exposed in an open drift is mostly a coarsely brecciated limestone (dolomite?) with some angular fragments of sandstone and quartzite a foot or more in diameter. Further down the hollow is a shaft said to be 70 feet deep and an open cut in the bed of a side stream entering Coon Hollow from the south. The rock here is limestone (dolomite?) and chert and these same rocks decayed in place to a straw color. The ores are zinc blende, zinc silicate and tallow clay, but most of the rocks cut in the shaft are barren. One bed of the clay is 10 inches thick and six feet long. That given in the following analysis came from this shaft:

Analysis of tallow clay from the Frisco. (633.)

Silica, SiO_2	37.04 per cent.
Alumina, Al_2O_3	8.85 per cent.
Zinc oxide, ZnO	37.76 per cent.
Ferric oxide, Fe_2O_3	1.68 per cent.
Ferrous oxide, FeO	0.42 per cent.
Lime, CaO	3.58 per cent.
Magnesia, MgO	0.77 per cent.
Soda, Na_2O	0.56 per cent.
Potash, K_2O	0.27 per cent.
Combined water, H_2O	8.76 per cent.
	99.69 per cent.
Moisture in clay at 115° C.	10.09 per cent.
Sand in air dried clay	5.84 per cent.

The zinc oxide of this analysis is equivalent to 30.27 per cent. of metallic zinc. When dry this clay retains its soapy "feel," but it breaks into small conchoidal and angular blocks.

Mr. E. J. Schmitz, a well known mining engineer of New York, examined this property in 1897 and estimates that "the whole ledge, as exposed in the face of the Frisco bluff, carries about 30 per cent. of workable ore, mostly blende."*

The Little Rock Placer claim is on the northeast side of Sugar Orchard Hollow in 19 N., 18 W., section 17, the southwest quarter of the northwest quarter, and about the middle of the south side. The opening is in Ordovician rocks and consists of an open cut 40 feet long, 12 feet deep and from 6 to 8 feet wide. About a third of this cut is in clay and rock decayed in place. The decayed rock contains much zinc carbonate, in streaks and pockets, especially near the mouth of the cut, while the solid beds of dolomite contain zinc blende. The zinc blende is found covered with a coating of zinc carbonate. Some of the open spaces have been coated with saddle-shaped crystals of dolomite, and these are covered again with a thin layer of smithsonite.

A second opening on the Little Rock Placer is 150 feet northwest of that just mentioned. It is a stripping from 50 to 60 feet in length up and down the slope and rising in steps 10, 7 and 6 feet high. It is mostly in clay and loose fragments of siliceous rocks—a mixture of chert and sandy quartzite with greenish streaks through it. Some zinc carbonate was found, but most of the zinc blende originally deposited in the now exposed parts of the beds has been removed in solution.

Big Mineral Placer claim is on Sugar Orchard Creek in 19 N., 18 W., section 17, the middle of the north half of the southwest quarter. The openings are in the Calciferous beds of the lower slopes of the hills between Sugar

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* Trans. American Institute of Mining Engineers, 1898, XXVIII, 267.

Orchard Creek and Mill Hollow, but facing the Sugar Orchard valley.

There are said to be some eight or ten openings on this claim, but only a few of them were examined. The first one is 70 feet up the hill and 1,000 feet N. 40 degrees W. from the house. It is an open cut 12 feet deep, 6 feet wide and 60 feet long, in brecciated sandstone and chert, some of it of a bluish-green color. The more weathered rocks contain zinc silicate in the crevices, but the unweathered chert contains disseminated zinc blende in small but abundant crystals. In places this chert has had the zinc crystals removed in solution, leaving it filled with angular cavities. Where the rock has been broken the small fractures are often filled with calcite containing small crystals of zinc blende. Some of the rocks have decomposed to porous friable masses; and there are a few streaks of tallow clay exposed in the cut.

A little further along (N. 70 degrees W.) the slope of the hill there is another open cut 30 feet long, 4 feet wide and 12 feet high on the face. A little zinc ore was found here both as silicate and as zinc blende.

A thousand feet further up the Sugar Orchard Hollow and on the same hillside is another open cut 40 feet long, 6 feet wide and 10 feet deep on the face. This cut is mostly in red and green clay and loose fragments, and the ore is zinc blende in the upper end of the cut where it enters the siliceous rocks. There is a good deal of zinc silicate in the loose material on the west side of this cut.

There are said to be five other openings on the Big Mineral Placer, but they are represented as showing much the same geology as those mentioned and were not examined.

The Found Indian claim is in a gulch opening southward into Sugar Orchard Creek in 19 N., 18 W., section 17, the west half of the northwest quarter. The geology is

like that of the rest of Sugar Orchard—horizontal Calciferous sedimentary beds in the bottoms of the narrow valleys with St. Joe marble high on the slopes and the Boone chert capping the hills.

There were five or six openings on this claim when it was examined in January, 1892; the principal one of these was a shaft 29 feet deep near the middle of the claim and on the east side of the gulch. There is a second shaft 10 feet deep on the west side of the same gulch; an open cut 200 feet north of the deeper shaft; and another open cut east of the same shaft. The 29-foot shaft is in clay with residuary boulders; these boulders have more or less zinc silicate attached to them, and the rock itself contains some zinc blende. Some tallow clay is also said to have been taken from this shaft. Some of the rocks contain cavities left by the removal in solution of crystals of zinc blende, and in many instances these cavities have been refilled with zinc silicate.

The shaft on the west side of the gulch is all in clay and loose material, and no considerable amount of mineral seems to have been found. The open cut 200 feet north of the main shaft is 15 feet long, 8 feet deep and 6 feet wide. The rock cut is coarse cherty breccia, containing small crystals of zinc blende. Some of the crystals have been removed from the rock by solution. The open cut 300 feet north of the main shaft is on the east side of the gulch near the top of the hill, and is 30 feet long, 10 feet wide and 15 feet deep. It exposes much clay and earth containing loose fragments of rock.

The zinc ores on this property are confined to certain beds, some of which are exposed naturally in the ledges about the head of the hollow.

The Last Chance claim is on the east side of Mill Hollow, in 19 N., 18 W., section 17(?). There is an open cut 35 feet long by 7 feet wide with an average depth of 6 feet

just below the St. Joe beds. The hard rocks are dolomites, but there is much clay exposed. In the clay are found many brown nodules or lumps supposed to be zinc carbonate. These lumps were examined chemically and found to contain very little zinc, and that in the thin seams.

The Mineral Hollow claims.*—Several mineral claims were examined along Mineral Hollow, but at the time of the examination it was not possible to find out the names or the precise locations of them all.

In its main features the geology of Mineral Hollow is very simple, and is like that of the rest of the Sugar Orchard Creek drainage. The Calciferous beds of the Ordovician are exposed in the bottom of the valley. These beds are composed of quartzites, cherts, sandstones, and siliceous dolomites. They are overlain conformably by the St. Joe marble, and this in turn is covered by the Boone chert beds. The zinc ores are found below the St. Joe marble, though there are a few exceptions to this rule; and for the most part it is below the saccharoidal sandstone. The most western opening showing zinc in Mineral Hollow is said to be in 19 N., 19 W., section 12, the southeast quarter of the southeast quarter. This is an open cut 20 feet long, 7 feet wide and 5 feet high. The rocks penetrated are dolomites, with thin-bedded chert overlying them, and the only ore found was a little zinc blende. About 40 feet above the open cut on the slope of the hill is the base of the St. Joe marble. Some zinc blende is found in little pits dug in the bottom of the hollow. This blende is partly covered with coatings of zinc silicate which upon analysis proves to be a very pure calamine.

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* Mineral Hollow is said to have received its name from the fact that much lead was mined here during the civil war. It has not been possible, however, to find out just where it was found or who did the mining.

The next claim to the east and further down the hollow is in 19 N., 18 W., section 18, the northwest of the northwest quarter. Twenty-five feet above the bed of the stream, there is an open cut in dolomite 35 feet long by 7 wide and 12 feet high at the face. Some zinc blende is found in this opening. It appears to be confined to a single bed, however. A little iron pyrites occurs in this same bed.

On 19 N., 18 W., section 7, the northwest quarter of the southeast quarter is another open cut on deeded land. It is 30 feet long by 20 feet wide and 12 feet high at the face. This is mostly in clay with residual rock boulders. The hard rocks are mostly of open texture as if some of their constituents had been leached out. The ores found here are zinc blende and zinc silicate.

On the east side of the hollow opposite the opening just mentioned is another small open cut in which no ore worthy of mention was found.

Another open cut known as "the spar mine," in 19 N., 18 W., section 7, is upon deeded land in the northeast quarter of the southeast quarter. It is on the side of a hill facing Sugar Orchard Creek. It is 25 feet long, 25 feet wide and 12 feet high on the face. The rock is dolomite seamed with dolomite spar. Large pockets of beautiful crystals of calcite are found in this opening, and from this it has taken the name of "the spar mine." Portions of these large crystals have been dissolved out and the cavities thus produced are lined with opaque calamine stained with red clay on the outside. The open cavities in places show that some of the rock has had zinc blende removed from it in solution. There is a streak of tallow clay from one to two inches thick across the cut. Considerable zinc silicate has been taken from this opening, but some of the material regarded as calamine is quartz.

The Gloria Mundi claim is above the Kansas claim at the head of Dry Hollow and on its north side, in 19 N., 18 W., probably in the southeast of the southeast of section 8. There is an opening 35 feet long, 12 wide by 6 feet deep. The rocks uncovered are somewhat jointed cherts of a bluish color where unweathered, but of a waxy yellow where somewhat altered by exposure. The unaffected parts contain an abundance of small crystals of disseminated zinc blende, while the weathered parts have cavities left by the removal of the zinc. The rocks are so much broken and jointed that they can be removed with a pick without blasting. The St. Joe marble bed crops out to the east and a little above the *Gloria Mundi* open cut.

On the same claim another open cut, 40 by 12 by 5 feet, on the south side of Dry Hollow exposes no ore of any kind.

The Coon Hollow mine is in 19 N., 18 W., section 8, near the middle of the south side. The openings are in the bottom of the hollow where the rocks all belong to the Calciferous group. The St. Joe marble is exposed on both sides of the hollow, both east and west, and above it the Boone chert caps the hills.

The openings are a shaft and an open cut. Perhaps the most striking feature of this property is the amount of tallow clay found in the workings. In the shaft this clay is 8 feet thick and it is also found in the bottom of the shaft, where it is mixed with zinc blende. When it is not too wet it can be broken out in lumps as big as a barrel.

Analysis of tallow clay from the Coon Hollow mine (359).

Silica, SiO_2	39.77 per cent.
Zinc oxide, ZnO	31.88 per cent.
Alumina, Al_2O_3	8.63 per cent.
Iron oxide, Fe_2O_3	6.75 per cent.
Lime, CaO	1.45 per cent.
Magnesia, MgO	0.68 per cent.
Potash, K_2O	0.84 per cent.
Soda, Na_2O	0.86 per cent.
Phosphoric acid, P_2O_5	0.19 per cent.
Loss on ignition, (H_2O, etc.)	8.46 per cent.
	98.96 per cent.
Water at 110°-115° C	11.69 per cent.

The zinc oxide in this clay is equivalent to 25.58 per cent. metallic zinc.

Another analysis of tallow clay from Coon Hollow has been made by H. N. Stokes of the U. S. Geological Survey.*

Analysis of tallow clay from Coon Hollow.

Insoluble	18.18 per cent.
Solnble silica, SiO_2	29.02 per cent.
Zinc oxide, ZnO	30.50 per cent.
Alumina, Al_2O_3	6.34 per cent.
Ferric oxide, Fe_2O_3	4.40 per cent.
Lime, CaO	1.91 per cent.
Magnes'a, MgO	0.75 per cent.
Loss on ignition, (H_2O, etc.)	8.86 per cent.
	99.46 per cent.

The zinc in this is equivalent to 24.47 per cent. of metallic zinc.

The ore found in the open cut is mostly smithsonite, but there is also zinc blende disseminated through chert. In many places these cherts show that zinc blende crystals have been removed from them in solution. There is also fine zinc silicate found at this mine, part of it clear and transparent and part of it dark and compact. A partial analysis of one sample was made which showed it to be calamine carrying the equivalent of 51.84 per cent. of metallic zinc. (689).

* Bulletin 168, U. S. Geol. Survey, p. 299.

Big Indian claim is in 19 N., 18 W., section 8, the southwest quarter of the southwest quarter and close to the section corner. The rocks are the horizontal Calciferous sedimentary beds. There is an open cut 30 feet long, 25 feet wide and 12 feet deep running into the hill from the bed of a stream. The rocks are broken dolomites above and cherts and quartzites below. The ore is mostly zinc blende with some zinc silicate in a bed six inches thick; there is a four-inch horizontal bed of pink tallow clay exposed on the walls of the cut at the same horizon as the zinc blende. The zinc silicate on this claim is found to be a very pure calamine. It occurs in thin crooked bands enclosing little pockets of reddish brown granular smithsonite. These bands of calamine are about an eighth of an inch thick; some of them are clear and transparent, while others are opaque and almost black. A little aurichalcite is found in these openings.

Other Sugar Orchard Prospects.—Several prospects of which the names are not known were examined in the Sugar Orchard Valley below Keener post-office. One of these on deeded land in 19 N., 18 W., section 7, northeast of the southwest is an open cut in a small side hollow on the right side of the valley. The cut is in horizontal dolomites of Ordovician age containing some chert nodules. The opening is about 20 feet above the floor of the valley, 40 feet long and 8 feet high on the inner face.

There is a horizontal streak of ore-bearing rock between the beds near the bottom of the cut. The ores are galena and zinc blende with some carbonates. The structural relations of the ore are shown by the accompanying section (Fig. 37).

The ore streak so far as exposed is from 6 to 12 inches thick. In all probability it extends up and down the valley side at about the same level. Whether it is anywhere

thick enough to work will have to be determined by further prospecting along the face of the hill.

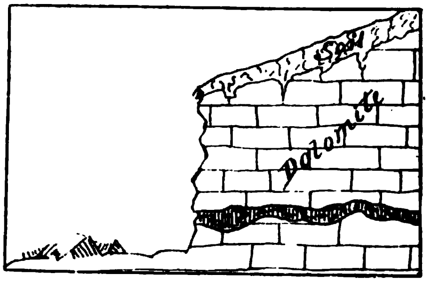


Fig. 37. Galena bearing bed in dolomite, upper Sugar Orchard Creek.

On a side gorge opening on the right side of Sugar Orchard Creek in 19 N., 18 W., section 18, east half of the northeast quarter. A little prospecting has been done in the bed of a small stream. The rocks are Ordovician, and the beds are about horizontal. One of these beds three and a half feet thick contains zinc blende. Beneath this bed a bed three feet thick has not been prospected and it cannot be stated whether or not it contains zinc. Below this last bed another bed of dolomite three and a half feet thick contains zinc blende. The ore in both of the ore-bearing beds in in vertical or approximately vertical cracks and irregular patches. So far as can be seen (July 9, 1900) the zinc ore is confined to horizontal Ordovician beds. The rock where uncovered is not rich enough to work, but rich deposits may possibly be found by prospecting along the outcrops of the ore-bearing beds.

In 19 N., 18 W., section 18, the southeast of the northeast quarter a pit has been opened in Ordovician dolomites, exposing vertical cracks containing zinc blende. The bed in which the zinc appears shows the same ore for a horizontal distance of 20 feet. The rocks at this point are slightly bent, but the ore-bearing bed will doubtless be found to encircle the valley.

In 19 N., 18 W., section 18, east half of the southeast quarter, there are five openings on the right side of the

valley and from 20 to 50 feet above it. These consist of open cuts and one shaft.

The rocks are horizontal dolomites or magnesian limestones and sandstones.

The 16-foot shaft at the foot of the hill found a little galena and zinc in siliceous dolomite, and a little zinc blende was found also in the open cuts near the top of the hill.

The Almy mine is in 19 N., 18 W., section 17, the northeast quarter of the northeast quarter, in a hollow that drains into Mill Creek on its right or northwest side.

The rocks exposed in the openings are of Ordovician age. They are mostly thin-bedded, of a greenish gray color, very siliceous, and many of them appear to have been leached of lime or some other ingredient. They resemble beds of angular chert fragments, and in places they form siliceous breccias, though, owing to the alteration of the rock, the fragments are often but dimly outlined. The beds are approximately horizontal, but the leaching they have undergone has left them gently sagging or with the appearance of being slightly folded. There is a gentle southeast dip (2 to 3 degrees) on the east side of the large cut. It is possible that there is a fault at this place, but the evidence is hardly sufficient to prove it satisfactorily.

The work done has all been in open cuts. One of these on the northeast side of the hollow is 100 feet long, 40 feet wide and 15 feet high on the inner face. The ores found here are chiefly silicates, carbonates and oxides of zinc. The silicate is by far the most abundant. There is a little zinc blende, but the crystals of blende found generally have an etched surface.

On the southwest side of the hollow are other smaller openings. The larger of these is about 50 feet long and exposes the rock to a height of 6 feet. The rocks in this

opening are very siliceous, and the ores are zinc silicate with some carbonate and a little blende.

Large quantities of "tallow clay" are found in pockets through the openings, but it has not been saved.

The Little Star is in 19 N., 18 W., section 20, the west half of the southwest quarter. The rocks are nearly horizontal Ordovician limestones that have a very slight dip to the east.

Opening No. 1 is a shaft 20 feet deep through limestone. A small amount of zinc blende was taken from the bottom of the shaft.

Opening No. 2 is on the opposite side of the creek and 60 feet above the creek level, and about 75 feet below the St. Joe marble. It is an open cut 40 feet by 30 feet, 6 feet deep at the inner end. The ore is smithsonite and blende. The ore streak is horizontal and is ten inches thick. Three or four tons of ore are on the dump. (A. H. Purdue, July 17, 1900.)

The Madison Placer is on the head of Still House Creek, a branch of Tom Young Creek, in 19 N., 18 W., section 30, the north half of the northeast quarter. The rocks are Ordovician sandstones and quartzites, much broken, but apparently not faulted. The rock is evidently the same as that at the Almy mine. The development is

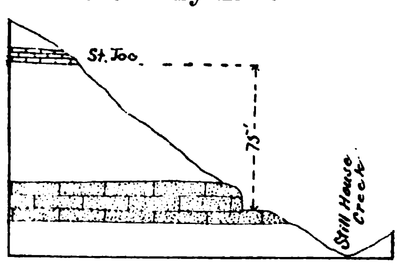


Fig. 88. Section at the Madison Placer.

an open cut or quarry 40 feet long, extending into the hill 20 feet with a 12-foot face at the inner end and 75 feet below the St. Joe beds. The ore is chiefly zinc silicate

with a very small amount of smithsonite and some zinc blende. The silicate is confined to the bottom six feet of the face. Five or six tons of ore are on the dump.

There is another opening across the ravine 150 feet N. 30 degrees W., from the open cut mentioned above. This is a cut into the hill 6 feet by 25 feet with a shaft 15 feet deep. The two cuts are about on the same level but the rock in the last mentioned one is much more broken than that in opening No 1. The cut has produced about one ton of ore-bearing rock, the ore being chiefly zinc silicate. There is no evidence of any vertical displacement of the rock on either side of the ravine. (A. H. Purdue, July, 1900.)

The Virginia J. is in 19 N., 18 W., section 29, the northwest quarter of the southeast quarter. The ore-bearing rocks are of Ordovician age and their horizon is about 75 feet below the base of the St. Joe marble. The rocks are slightly disturbed limestones. The development consists of a cut 40 feet long in the bed of a creek, and a shaft 18 feet deep with a short drift opening out of it. The cut is in limestone and is of uneven depth, but averages about

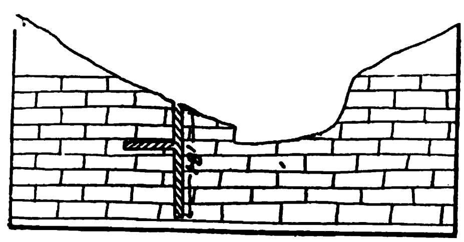


Fig. 39. Section of the cut and shaft at the Virginia J.

6 feet. The shaft is filled to creek level with water, but it is claimed that a large amount of zinc blende was taken from the drift leading from the shaft. The ore is all blende and occurs in good quantity associated with calcite in the joints of the fractured limestone in the bottom of a synclinal trough, whose sides both have a low dip and whose length cannot be made out because of the short ex-

posure. On the north side the dip can be seen for 150 feet along the creek. The syncline apparently pitches to the west. About 10 tons of rich ore rock are on the dump.

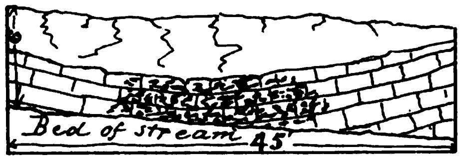


Fig. 40. Section along the stream bed showing ore in a syncline at Virginia J.

There is an opening 180 feet further up the creek, almost as large as the one above mentioned, but no ore was found in it. (A. H. Purdue, 1900.)

NOTES ON OPENINGS ON CROOKED CREEK.

The Roberts property is on the east bank of Huzzah Creek in 18 N., 19 W., section 10, the northeast of the northeast quarter. One opening is a small pit 3 feet above the creek in compact limestone. Zinc blende occurs here in joints in the limestone in the trough of a synclinal fold.

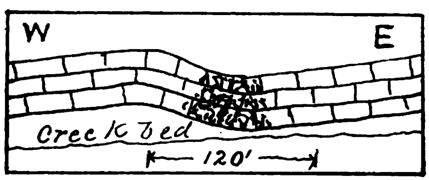


Fig. 41. Section at the Roberts property, showing ore in a syncline.

A quarter of a mile west of the Roberts pit No. 1 on the flat land of the creek bottom, is a small opening in the same kind of rock as opening No. 1. This rock is here rich in zinc blende, and contains some smithsonite. Most of the ore is in the joints of the rock, but there is also a small amount of disseminated ore. (A. H. Purdue, 1900.)

The McDonald mine is on the east bank of Huzzah Creek in 18 N., 19 W., section 9, the northwest quarter. The rocks are of Ordovician age and approximately horizontal.

Opening No. 1 is an open cut in limestone and about 40 feet above the creek level. About 40 cubic yards of rock have been removed from the opening. The ore-bearing rock consist of two layers aggregating 2 feet in thickness, and through these the ore is disseminated. It is chiefly smithsonite, with some zinc blende. The rock dips north at a low angle for a distance of 600 feet south of the opening.

Opening No. 2 is 180 feet north of and 20 feet lower than No. 1. There have been about 20 cubic yards of rock removed, showing a small amount of blende in pockets. The rocks dip to the south at a very low angle.

Opening No. 3 is 90 feet north of No. 2; about 18 yards of rock have been removed, probably one and a half tons of rock containing disseminated smithsonite and zinc blende have been produced. Only a six-inch stratum of ore-bearing rock shows in this cut. The rock is undisturbed except a low dip to the south, which, however, is only a small flexure, the rocks dipping to the north only a short distance away. (A. H. Purdue, 1900.)

The Smith property is in 18 N., 19 W., section 9, the southwest quarter, in the yard of Mr. Jesse Smith. The rocks are brecciated Ordovician limestones. The opening is 10 feet by 15 feet, 8 feet deep in rock, with 2 feet of soil at the top. The ore is both smithsonite and zinc blende cementing brecciated limestone. (A. H. Purdue, 1900.)

The Joplin Flint is in a small ravine running into Huzzah Creek, in 18 N., 19 W., section 4, the southwest quarter. The rocks are Ordovician limestone. The opening is 350 yards north of the creek and 40 feet above it, and consists of a cut 8 feet by 20 feet, 7 feet deep, chiefly in clay and loose rock. The ore is chiefly disseminated zinc blende in loose blocks in the clay. Ten feet east of this opening is another from which about 10 cubic yards

of clay and loose rock have been removed. A small amount of smithsonite was taken out of this cut. Like the first, it was made in a small hillside cavern in Ordovician limestone. (A. H. Purdue, 1900.)

The Starkey opening is by the roadside 250 yards east of the "Joplin Flint" and on the same level. The opening is 10 feet by 10 feet, 6 feet deep at the inner end, with clay at the top and 2 feet of decomposed cherty limestone in the bottom. About one ton of smithsonite was taken out of the cherty limestone. (A. H. Purdue, 1900.)

The Denison mines are on the banks of Crooked Creek in 18 N., 19 W., section 6, the northeast quarter. The rocks penetrated are all horizontal Ordovician limestones. The development consists of three shafts and one quarry or open cut.

Shaft No. 1 is 29 feet deep. When visited (July 18, 1900) it was filled with water to within 16 feet of the top. The ore is said to have been taken from the bottom of the shaft. The ore is entirely zinc blende, sparingly distributed through the cavities.

Shaft No. 2 is 20 feet deep and is wholly in stream gravel. In this no ore was found.

Shaft No. 3 was 22 feet deep when visited (July, 1900.) At the bottom was a short drift running toward the south. This tunnel follows a horizontal bed of ore 2 feet thick in limestone. The ore is zinc blende, which occurs in small pockets or lenses along the bed. Very little

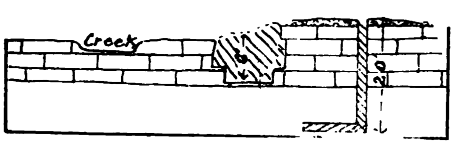


Fig. 42. Section at opening No. 3, the Denison.

ore was found in the shaft above this streak. The rock of the shaft is jointed, but otherwise undisturbed. Between tunnel No. 3 and the creek is a quarry or open cut 30 feet

long and 6 feet deep, as shown in the accompanying section. This cut is in compact limestone; it yielded no ore except a small amount of zinc blende on either side of a joint that runs N. 10 degrees E. lengthwise of the quarry.

A small amount of zinc blende occurs in the joints of the rock in the creek bed near the quarry. It also shows in small amounts in the joints in the creek bed 180 feet further up the creek from this point. The owners of the property are completing a steam plant of 100 tons capacity. (A. H. Purdue, 1900.)

A prospect in 18 N., 18 W., section 7, the northeast quarter shows a small amount of disseminated blende in horizontal Ordovician limestone. This is probably 60 feet above Crooked Creek and just beneath a bed of sandstone that appears to be the same as that in which the Almy and Madison Placer occur. (A. H. Purdue, 1900.)

A prospect at Killebrew's store in 18 N., 18 W., section 8, the northwest quarter, shows zinc blende disseminated through limestone in the bed of a branch of Crooked Creek. (A. H. Purdue, 1900.)

There is a prospect in 17 N., 20 W., section 3, northeast quarter of the northeast quarter, on a branch of Crooked Creek.

The rock is breccia, apparently the St. Joe marble bed mixed with fragments of the Boone chert. The development consists of a hole 12 feet deep. The ore is zinc blende in the disseminated form. The ore is chiefly in the limestone, but there is some in the chert. There is but little of it and it is apparently only near the surface. (A. H. Purdue, 1900.)

Rossin shafts.—The rocks of all the high country in the immediate vicinity of Harrison belong to the Boone chert series. The upper portion of Crooked Creek flows over the Boone chert, but three-quarters of a mile east of Harrison this stream has cut its way down through the

cherts and limestones, and from this point down to its mouth it flows over rocks of Calciferous age.

Rossin shaft No. 1 is four miles east of Harrison in the valley of Crooked Creek, in 18 N., 19 W., section 6. The rocks in the immediate vicinity of the shaft all belong to the Calciferous series, and consist of dolomites; the Lower Carboniferous beds are about 50 feet above the mouth of the shaft. When this place was visited in December, 1891, there was a shaft 29 feet deep: 3.5 feet of soil, 25.5 feet in siliceous dolomites. In the bottom a dark siliceous dolomite contains some disseminated zinc blende. At the time of the visit no large body of ore had been struck. A little iron pyrites and a little chalcopyrite were seen in the rocks of the shaft.

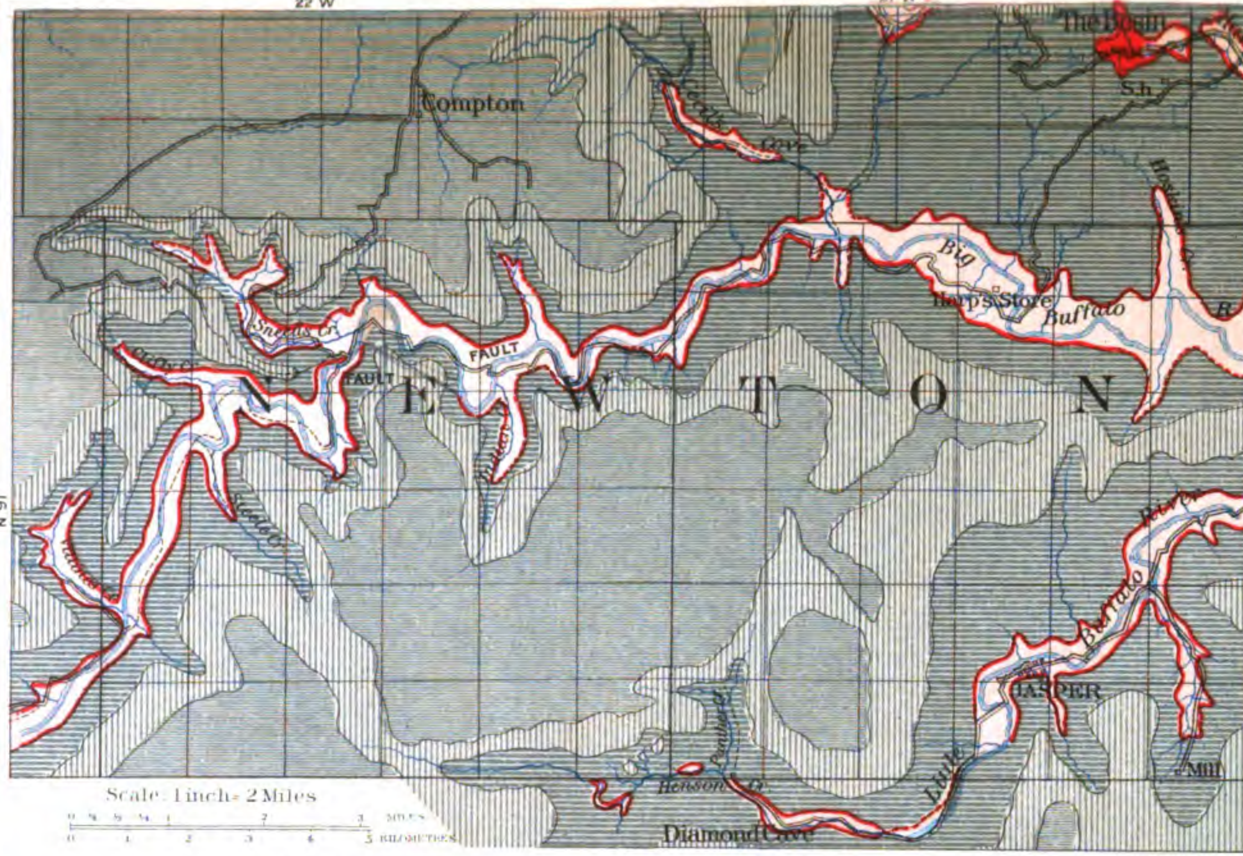
On the hillside east of the shaft are many fragments of spongy siliceous rock having its many cavities lined with small quartz crystals. These quartz-lined cavities were formerly regarded as "signs of ore," but experience has shown that they have no necessary connection with it.

Rossin shaft No. 2 is about 200 feet southwest of No. 1, 20 feet lower, and at the edge of Crooked Creek bottoms. This shaft when visited in 1891 was 25 feet deep, the uppermost 7 feet being in soil. The rocks penetrated are all siliceous dolomites, more or less porous and having some of their cavities filled with zinc blende, quartz and dolomite spar. The crystals of zinc blende sometimes adhere to the quartz crystals, and sometimes the quartz adheres to the blende.

NOTES UPON THE NEWTON COUNTY REGION.

The Mill Creek Zinc Deposits.

The Marble City and Canton mines on Mill Creek belong to the same class of deposits, and it is probable that the zinc ores along this stream will be found under about the same conditions. The ores are apparently confined to



GEOLOGY OF THE REGION ABOUT JASPER AND BIG BUFFALO.

JULIUS BIEN & CO. N.Y.

The open cut at the Marble City mine on Mill Creek.

a well defined and easily found horizon, which is from 50 to 75 feet below the base of the saccharoidal sandstone. These ore-bearing beds will be found richer along certain belts, but the location of these belts can be determined in only two ways: first, by a geological study; second, by actual exploration. In most places the ore-bearing bed will be found too poor in zinc to be workable. The rich deposits will be found along gentle folds, and possibly near small fault lines.

The Lower Carboniferous rocks in which the zinc and lead are found in the vicinity of Boxley and in Henson Creek cap the hills north and west of Marble City, and it is possible that fractures similar to those about Boxley are to be found in the vicinity of Marble City. In case they occur there, they may be looked for in the tops of the flint hills between Marble City and Boxley. The ores in these breaks in the flint beds will not follow horizontal strata but will run up and down the hills, as they do on Big Buffalo Creek.

The Marble City mine is in 17 N., 20 W., section 29, southeast of the southwest, and is on Mill Creek south of

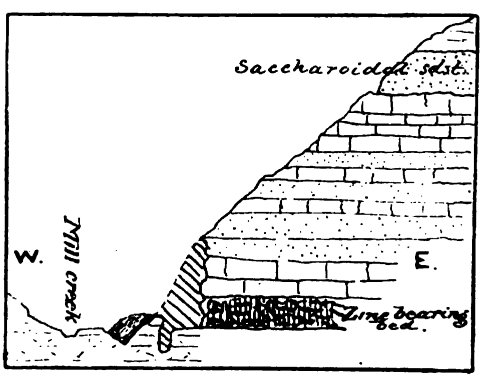


Fig. 43. Section at the Marble City on Mill Creek.

Marble City, Boone County, or Wilcockson post-office. The opening on this property is an open stripping at the

foot of a steep hill on the left bank of Mill Creek. On the side of this hill the saccharoidal sandstone is exposed with a thickness of about 75 feet. The stream has been diverted from its channel to enable the miners to get at the bed at the base of the bluff. (See Fig. 43.)

The rocks exposed in the workings are horizontal beds of Ordovician age, about 50 or 60 feet below the base of the saccharoidal sandstone. The cut is 120 feet long and 25 feet deep, and there is a winze six and a half feet below the floor of the cut, but it was filled with water when the place was visited in June, 1900.

The zinc is mostly blende, but there is also some zinc carbonate. The zinc—both the blende and carbonate—seems to be confined to one bed of quartzose sandstone which is from 6 to 8 feet in thickness, and running the entire length of the quarry.

At some places the zinc-bearing bed is stained green as if by copper, and a few small crystals of chrysocolla (hydrous copper silicate) are found in the cavities through the bed. There are also some patches of tallow clay in the cavities in this zinc-bearing bed.

Canton is the name given several prospects on Mill Creek in 16 N., 20 W., section 6, southeast quarter. The rocks are horizontal siliceous beds with calcareous streaks

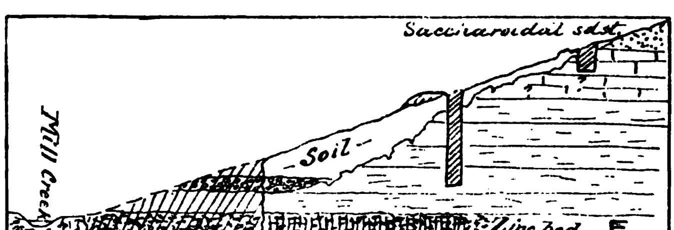


Fig. 44. Section at the Canton openings on Mill Creek.

in them. They are of Ordovician age, and the ore-bearing bed is some 50 or 60 feet below the base of the great saccharoidal sandstone.

One of the Canton open cuts on Mill Creek.

The zinc occurs at the level of the creek disseminated through one of the horizontal siliceous beds, but this bed extends below the water. The total thickness of the ore-bearing bed was not seen, but it is said to be 6 or 7 feet. There are several openings on this property, but the rocks exposed in the three shafts and two open cuts examined point to the conclusion that the zinc ore at this place is mostly confined to a single approximately horizontal bed. In the open cut on the left bank of the stream at one place where the cut makes a right angle bend, the zinc blende passes into the bed above the chief zinc horizon.

The ore body at the Canton mines seems to be at or near the same geologic horizon as that at the Marble City openings further up Mill Creek.

The Boxley Group of Mines.

The mines seen at and near Boxley are on or close to faults and the ores are found mostly in the fractured materials filling the crushed zone of these faults. The mines yield both lead and zinc; some of them have only lead, others only zinc, while still others yield both. The ore is generally confined to the area of crushed rock along the fault, but a little ore is sometimes found in the walls on either side of the fracture.

The faults seen in the Boxley district are nearly vertical and the walls are sometimes beautifully slickensided.

The fractured zone where seen is from two to more than a hundred feet wide, but it is to be expected that this belt will widen at some places and contract at others. This statement applies to both vertical and horizontal exploration. Whether or not the ore in these faults will become more abundant or less abundant with depth we have no means of knowing at present. The locations and directions of the faults in the Boxley have not been determined except at a few points. There are several of these faults,

however, and some of them are parallel, but it is not likely that they all have the same direction.

Prospecting should follow these fault lines until the richest places are found. In attempting to follow the faults, however, it should be remembered that they are only approximately straight, that they are liable to die out, and that there are several sets of them.

The ores of this district are in fissure veins in Lower Carboniferous rocks, and are, in this respect, in marked contrast with the ores of Boone, Marion and Baxter counties, which are bedded deposits in rocks of Calciferous age. It is not improbable, however, that the bedded Calciferous deposits exist in this district. If they do exist they will be found below the great saccharoidal sandstone bed along Big Buffalo River or some of its tributaries.

Peck's lead mine is in 15 N., 23 W., section 16, northwest of southeast, on the south side of Edgmon Creek. It is an old lead mine and was owned and worked by the Missouri and Arkansas Mining and Prospecting Company in 1882 and 1883. They erected a smelter in the valley below the mine where the ore was reduced. Two car loads, 80,000 pounds of pig lead, from this mine are said to have been hauled to Eureka Springs, and thence shipped by rail. The Missouri and Arkansas Mining and Prospecting Company closed out in the spring of 1883. Mr. Peyton began work at the mine in 1890.

The ore, free galena, is in the limestone and chert at the top of the Boone chert series, which at the mines is nearly all limestone. The ore nearly all occurs in the cavernous openings in the limestone, in the face of a steep bluff over 200 feet high. The openings are tunnels and open cuts run in the face of the bluff from 90 to 120 feet above the creek. Three of the tunnels are from 25 to 100 feet long. About 1500 pounds of galena lie on the dump at one of the drifts. Overlying the chert and limestone on

Bluff of saccharoidal sandstone on the west side of Big Buffalo below the mouth of Villines' Creek, looking southwest.

top of the bluff is the Batesville sandstone in which several shafts have been sunk. In some places the sandstone rests directly on the chert, in other places there is black and greenish shale several feet thick between the chert and the sandstone. There are boulders of Millstone grit and Archimedes limestone along the stream and on the slopes, but they are fragments that have rolled down from the mountain above.

A chemical examination of the limestone gangue from this mine shows it to contain some silica, alumina and iron and a trace of strontium.

The Last Chance (in Newton County), formerly called the *Jenny Bell*, is in 16 N., 23 W., section 19, the northwest quarter. The rocks belong to the Boone chert of Lower Carboniferous age, and are cherts, limestones and breccias. There is a shaft 12 feet deep in chert breccia. Enormous masses or boulders of this weathered chert breccia are scattered over the surface of the ground around the mouth of the shaft. In the shaft the north face appears to be of unbroken chert beds, while the shaft itself penetrates the fractured chert. Twenty feet southwest of the shaft the limestone and chert are unbroken, but dip south at an angle of from one to two degrees.

The ore seen here is all zinc carbonate. Much of it is in the form of small grains hardly larger than a pin head filling little cavities through the chert breccia; in other cases the carbonate occurs in big almost solid lumps. Some of these lumps lie scattered and weathered over the surface of the ground. (T. C. Hopkins, Feb., 1892.)

The Bennett mine is in 16 N., 23 W., section 35, two and a half miles below Boxley, on the north side of Buffalo River and on the ridge between the river and a small tributary known as Clark Creek. The mine has been in operation at intervals for more than three years (December, 1891), in which time 100 tons of zinc ore have been ship-

ped. The ore was sent by wagon to St. Paul in Madison County and thence shipped by rail to the Weir City Zinc Company. The cost of mining is reported at $2 per ton, the teaming to St. Paul cost $10 per ton.

The ore is a porous yellow to grayish colored zinc carbonate, beautifully banded and compact. It occurs in and near the line of a fracture at the top of the Boone chert series. The St. Joe marble, the bottom of the series, outcrops at the base of the hill, 415 feet below the mouth of the main shaft in the mine which is approximately the top of the chert. The upper part of the chert bed is almost entirely limestone, the chert consisting of small lenticular masses in the limestone. The Batesville sandstone and shales occur on the hill above and west of the mines, and the Millstone grit higher on the mountain. The direction of the break in the rocks varies at different places on the line; in the drift from the main shaft it is south 5 degrees east, while in one other place south of the shaft it is south 40 degrees west. No displacement either vertical or horizontal was observed, the fracture appearing to be a simple break, the solid walls on either side varying from 2 to 20 feet apart, the interval being filled with chert and limestone fragments, clay and zinc ore. Comparatively large bodies of the ore occur in places almost free from gangue. The operations are in the line of this break in which a shaft has been sunk 35 feet from which there is a drift running south 75 feet on the line of the break, with cross-cuts and stopes to the east.

On the hill south of the shaft now worked are eight or more old shafts from some of which lead or zinc ore has been taken at different times; some of them were worked in time of the civil war. One of these is a cave-like opening in the limestone in which a shaft has been sunk 25 feet and from which it is reported that 50 tons of lead ore (galena) were taken during the civil war. Another old

shaft 25 feet southwest from the lead shaft is reported to have been 60 feet deep, and to have furnished some zinc carbonate ore. (T. C. Hopkins.)

Villines property. In 16 N., 23 W., section 25, the northwest quarter of the northeast quarter is a shaft on the property of Mr. Villines which has produced zinc silicate. The ore is in the Boone chert 230 feet above the Calciferous and 130 feet below the Batesville sandstone. Above the shaft on the hill the chert and limestone are in place; below the shaft the hillside is covered with loose debris. The shaft appears to be in the line of a fault or break, but the shaft being timbered and the surface covered with loose fragments, nothing definite could be ascertained in regard to this supposed fault. Several tons of zinc silicate are on the dump. The gangue is a chert and limestone breccia. The ore occurs in pieces of a few grains to several pounds in weight.

The Idaho mines are in 16 N., 23 W., section 24, east half of the southwest quarter on the south side of Villines Creek. There are other adjoining tracts belonging to the owners of this property.

The openings are all in horizontal beds of the Boone chert series, and consist of several open cuts, shafts and tunnels. It is not known that any ore was found in the uppermost openings. In one tunnel 18 feet long, made in the gray limestone of the Boone chert, a pocket of zinc carbonate and zinc silicate yielded some good ore. Slickensides on the walls of this tunnel show that the rocks here have been displaced horizontally.

North of this tunnel and on a level with it is a well-timbered shaft 36 feet deep, from which a considerable quantity of good zinc silicate was taken. There is a very little zinc blende mingled with the silicate. A tunnel 100 feet long enters the hill 36 feet below the mouth of the shaft and running S. 80 degrees E. (magnetic) cuts

the shaft at the bottom. This tunnel exposes slickensides at several places.

In the tunnel 24 feet from the mouth are streaks of galena in places three inches wide. This is the only ore seen in the tunnel between its mouth and where it enters the shaft. At the inner end zinc silicate is found. It was reported to me that the galena taken from the tunnel was assayed for silver, but that none was found in it.

Lower down the hill and about 40 feet from the above-mentioned tunnel another drift was started, but it was abandoned after being driven seven feet. No ore was found in this last mentioned opening. Still further down the hill a tunnel 20 feet long in the Boone chert has been driven westward from the bottom of the gulch. No ore is exposed in it.

The openings on this property thus show calamine in the decomposed and altered rocks and a little galena in the unaltered limestones and cherts of the Boone chert series. The rocks have been fractured somewhat, but if the faults found on the neighboring properties pass through this one, they have not yet been clearly and definitely located.

The Boxley mine is in 16 N., 23 W., section 3, southwest quarter of the southeast quarter, on the land of Joseph Villenes, about an eighth of a mile north of Boxley post-office, Newton County, and on the west side of Big Buffalo River. The openings are in rocks called the Boone chert, and are of Lower Carboniferous age. These openings consist of a tunnel one hundred and fifty feet long, entering the hill about eighty feet above the valley, an open pit 15 feet deep about 60 feet above the tunnel, and of a second tunnel about 30 feet long above the open pit. These are on the side of the hill as shown in the accompanying sketch (Fig. 45).

Of the long tunnel, the first 40 feet is in the Boone chert; beyond that the rocks are all more or less broken and the chert breccia is mixed with dolomite, zinc blende,

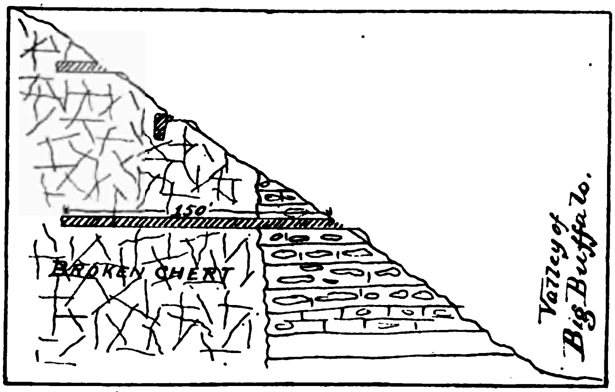


Fig. 45. Section at the Boxley tunnel.

and calamine (zinc silicate). The calamine is mostly in thin veins or bands. The tunnel does not pass out of the zone of crushed rock.

About 60 feet up the hill above the mouth of the tunnel the open pit is in the broken limestone and dolomite of the Boone chert series. In this pit some disseminated zinc blende and a little calamine was found.

The upper tunnel is altogether in the crushed rock. A little zinc blende was found in it.

The Baker and McGrath group of mines is in 16 N., 22 W., section 18, southwest quarter, on the north side of Villines Creek, which is also known as Add's Creek.

The openings are on the side of a high hill. This hill is capped with Batesville sandstone; beneath the sandstone is a bed of marble or encrinital limestone, and beneath this are the limestones and cherts of the Boone chert series of the Lower Carboniferous, all of them approximately horizontal. The openings are all in the Boone chert series.

About 50 feet below the crest of the hill is an open drift 40 feet long cutting fossiliferous limestone and

pockets of clay. Only lead was found in this drift; it occurs in the limestone as large crystals of galena with some lead carbonate. It is stated that between 5,000 and 6,000 pounds of galena were taken from this cut.

Three hundred feet northwest of the above mentioned drift are several other openings, including a 40-foot shaft and an open cut from 6 to 12 feet wide, from 10 to 20 feet high on the upper side and from 50 to 60 feet long, besides several other open pits. These are all in nearly horizontal rocks of the upper part of the Boone chert series, but they are upon a fault. This fault runs north-south (magnetic) and has the downthrow upon the east. The amount of the displacement could not be determined when the property was visited in July, 1900.

The ore is both zinc blende and galena, some of it mechanically mixed; there is also some smithsonite and some lead carbonate in the clays and earth-filled cavities near the surface. The ores are scattered through the crushed zone of chert, clay and marble that follows the fault. The walls of the fault are well defined, but the west wall is much decayed in place while the east wall seems to be un-

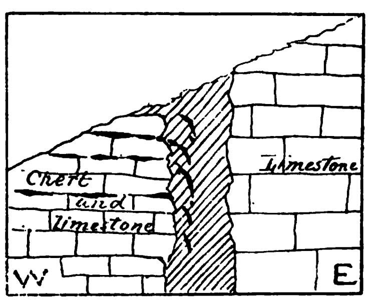


Fig. 46. Section at the Baker and McGrath shaft showing the faulted chert.

affected. At the south end of the open cut the chert on the west side drops down and into the crushed zone, while the east wall just opposite contains no chert.

The ore-bearing zone is uncovered for a distance of 120 feet with a width of from 5 to 8 feet. The rock con-

Looking north at the vein and fault, Baker and McGrath mine, near Boxley.

taining the ore is a soft limestone that will crush easily; some of it has already decayed and left the galena free. The galena is in lumps and in streaks of various sizes cutting the rocks.

Plate XVI is a view of the vein at this opening. The vein is vertical, its west wall is in line with the corner of the building behind the man in the middle background, and the east wall is the face on the right of the foreground with the timber sticking in it.

About 1000 feet northwest of the shaft above mentioned along the face of the same hill and about 100 feet below is a small opening in the Boone chert from which some excellent smithsonite is said to have been shipped. It is an open cut 20 feet long by 10 feet high on the upper side. The ore is in a broken chert on a fault.

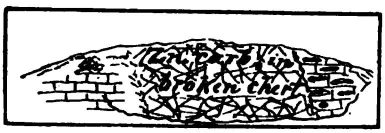


Fig. 47. Face of a cut on a fault at the Baker and McGrath.

Twelve feet below this cut is a drift 20 feet long from which a considerable amount of excellent banded smithsonite has been taken.

Thirty feet below this drift is a tunnel 45 feet long, mostly in clay gangue and broken rock. The rock forming the east wall in this tunnel is fossiliferous limestone. The tunnel ends in a vertical cavern.

The ore from the last three openings is practically all smithsonite. There are only a few partly decomposed crystals of zinc blende and no lead.

Thirty-five feet below the last mentioned tunnel is still another one—the lowest on this property. It is about 40 feet above the bottom of the hollow (Villines Creek), is 50 feet long and in the limestone of the Boone chert series all the way. The mouth of this tunnel starts in the vein

or fracture that passes through the openings further up the hill, but its course is to the north or northeast, so that it leaves the fracture on its west side and no ore body was found except near the mouth of the tunnel.

The fracture on which these openings are located bears north 30 degrees east (magnetic).

Lead prospect. In 16 N., 22 W., section 18, east half of the northwest quarter and the west half of the northeast quarter there is a lead prospect on the north side of the hill, and about half a mile west of F. W. Walker's place. Walker's house is on the Carboniferous sandstones. Half a mile west of his house and north of the road there has been a big landslide in a gully on the north face of the hill. Passing down this gully from the road one passes over Carboniferous sandstone at the road. Beneath this is black, thin-bedded shales and below the shale are beds of fossiliferous limestone. In an open cut made in this limestone in the bottom of the gully considerable galena was found. The cut is twenty feet long and ten feet deep at the upper end. It is now almost entirely filled with debris from the landslide. (T. C. Hopkins.)

The Cutler Diggings are in 16 N., 22 W., section 18, the northeast quarter of the southwest quarter at the top of the Boone chert series, and 300 feet above the creek at the Bed Rock claim. The rocks are apparently *in situ* undisturbed. The ore exposed on the surface and now being mined is zinc carbonate and galena. Galena has also been mined through a deep shaft, and there is some of it scattered through the spongy masses of smithsonite.

In 1877 or 1878 Mr. West Birney sunk a shaft 75 feet deep and took out enough lead ore to produce 75,000 pounds of pig lead. The smelting was done by Mr. Vipon; the smelter was about one mile southwest from the mines in 16 N., 23 W., section 24, the northeast quarter. There is no record of any work from that time to 1891 when ore

was shipped to Pittsburg, Kansas. It was ore that had lain on the dump for a number of years. It went by wagon to St. Paul, Madison County, and by rail thence to Pittsburg, Kansas. (T. C. Hopkins.)

The (Boxley) Bonanza mines are in 16 N., 22 W., section 19, northwest of the northwest.

The rocks are all of the Boone chert series, the beds are horizontal and apparently undisturbed, and the openings are in or near a gully that drains into Villines Creek on the left side. The lowest opening, about 600 feet southeast of the creek, is a cut in gray limestone, about 30 feet long and 5 feet deep. No ore was found in this cut.

One hundred and twenty-five feet further up the gulch there is a shaft 28 feet deep penetrating Boone chert, clay and other loose material. The ore taken from this shaft is nearly all zinc carbonate, but there is also a little zinc blende with it.

Thirty feet further up the gulch is a pit 10 feet deep put down in the bottom of the gully. Overhanging the pit are big blocks of more or less weathered chert containing considerable zinc carbonate. There are other small surface openings further up the gulch and one pit fifteen feet deep on the northeast side of the gully, each of them showing more or less smithsonite.

The Chimney Rock mines are on the north face of a high hill in 16 N., 22 W., sections 7 and 18, near the head of a ravine tributary to Clifty Creek. The openings are near the top of the Boone chert series, the overlying Carboniferous beds being exposed at the road that passes along the face of the mountain a few hundred feet above the mines. These mines are upon a fault having a horizontal displacement, but so far as I could determine after a brief examination very little vertical throw. The walls of the fracture are beautifully slickensided, the strike being nearly horizontal. One of these walls is shown in the ac-

companying plate (plate XVII) taken in an open cut worked many years ago, and now overgrown with bushes. The vertical walls are from 2 to 10 feet apart, and the space between them is filled with broken chert, limestone, clay, dolomite and galena, the chert being most abundant. This vein matter has been worked out where mining has been done, but where it is still undisturbed on the surface, it rises above the surface here and there along the fault-line like the broken patches of an ancient and irregular wall. These masses are from 3 to 10 feet wide at the base and from 3 to 30 feet high. The mine takes its name from one of these chimney-like masses that has a height of 30 feet and a width at the base of about 15 feet. The general direction of these outcrops and hence of the fault at this place is S. 25 degrees W. (magnetic). One of these open cuts on the vein bears S. 20 degrees W.

The workings consist of a number of open cuts along the fault line, and one tunnel 55 feet long driven in the hill below the outcrop of the vein for the purpose of striking the ore at a depth. At the end of this tunnel is a winze 44 feet deep. The tunnel passes through the barren Boone chert rocks, and the winze was probably planned to go down upon the fractured lead-bearing zone. If any ore was found in this tunnel or shaft it was very little. It is possible, however, that the tunnel did not go far enough to reach the main fault. Considerable galena is said to have been taken from the open cuts in the early history of these workings. The ore is good but not abundant. It is found mostly in the breccia, but there are occasional cubes in crevices in the wall rocks. An analysis reported to have been made of galena from the Chimney Rock mines showed it to contain over an ounce of silver to the ton.

The slickensided wall in the open cut of the Chimney Rock vein.

THE LITTLE BUFFALO REGION.

The Jackpot mine is in 15 N., 22 W., section 22, south-east of the southwest, on the right bank of Little Buffalo Creek and in the bluffs that overhang that stream. The valley of Little Buffalo Creek at this place is scarcely more than 500 feet wide on the bottom. The slope on the west side is a steep soil slope, but on the east side it is a perpendicular bluff of Boone chert from 75 to 100 feet high. The walls of the bluff are bare and gray—almost white—and the beds of rock are not quite horizontal. They belong to the Boone chert series.

The openings consist (July 3, 1900) chiefly of a broad face blasted from the bluff. This open quarry-like cut, extends from near the top of the bluff down to within about 30 feet of the usual level of the creek. The rocks exposed in the bluff for 1000 feet or more below the mine have a south (upstream) dip of from two to four degrees. This dip is pretty regular up to the Jackpot mine, where the beds bend down more sharply toward the break in which the mine is opened. On the north side of the cut in the top of the bluff the rocks dip 10 degrees to 12 degrees to the southeast. Near the middle of the cut the dip is S. 70 degrees E. about 20 degrees. High up the face of the cut the dip is about east. Near the south side of the opening the wall rocks of the bluff in place dip N. 60 degrees E. When platted these dips show that the rocks in the opening dip toward each other forming a short abrupt folded trough (syncline) that dips into the bluff. This fold is not wide, for 80 feet south of the mine the rocks dip S. 30 degrees E. at an angle of only two or three degrees.

The rocks exposed in the cut are bent, broken and in places much decomposed, and there is a good deal of clay in the middle of the cut, that seems to have been washed into an old cavern. Calcite in the form of "onyx" and

"nail head spar" is very abundant in these rocks. The ore found is chiefly zinc carbonate, but there is also some disseminated zinc blende. Some of the ore looks like a replacement of gympsum by the smithsonite.

Plate XVIII shows the broken condition of the rocks in this cut. Some idea of its structural features may be had from this illustration.

It is not possible to speak with certainty about the nature or amount of ore to be expected in this property, but the writer's observations in the zinc regions lead him to anticipate that the most hopeful direction for seeking the ore will be along the trough of the fold exposed in the cut.

The Low Gap mine is in 15 N., 22 W., near the center of section 11. It is outside of the Henson Creek valley on the side of a small ravine that drains into Little Buffalo River.

The development consists of a shaft 50 feet deep timbered to a depth of 40 feet. The shaft is in and near the top of the Boone chert on the west side of a ravine and on the upthrow side of a fault, which the ravine follows. Joining this ravine 450 feet south of the shaft is a second ravine, that runs N. 45 degrees W., which also follows a fault with the downthrow on the south side and being 100+ feet.

The ore is galena, smithsonite, and blende. The galena is exposed in the limestone about the mouth of the shaft in small crystals from a quarter of an inch to an inch in diameter. It is reported that more or less galena was found all the way down the shaft. Smithsonite and blende are said to have extended all the way down also. Near the bottom of the shaft a small amount of onyx was taken out.

Five or six tons of ore are on the dump, part having come from the shaft and part from the rock outcropping about it. This is one of the oldest prospects of the locality. (A. H. Purdue, 1900.)

The fractured zone in the open cut at the Jackpot.

The Panther claim is in 15 N., 22 W., on the section line between sections 1 and 2 a quarter north of the section corner. It is in the Boone chert on the line of the fault. Large masses of limestone-chert breccia occur in the fracture of the fault in the midst of which the zinc occurs in masses as a porous, soft, light-colored carbonate. The openings are an open cut and pit. On the east side of the fault the rocks dip 5 degrees to 10 degrees away from the fracture; on the opposite side they are apparently horizontal.

The Lamar mine is in 15 N., 22 W., section 33, the northwest quarter of the northwest quarter.

Opening No. 1 is a cut running north into the hillside. It is 8 feet wide, 15 feet long, with a face of 12 feet at the inner end. The cut follows what is either a fissure or a cavern in the Boone chert, which at this point is almost wholly limestone. The ore consists of zinc silicate, zinc blende, smithsonite and galena. The cavern or fissure followed by the cut is 8 inches wide and dips 80 degrees N. 70 degrees E. It is filled with silicate and smithsonite in clay.

The blende occurs in veins a quarter of an inch thick in the limestone. The galena is imbedded in the clay and also occurs in small pockets in the limestone. When in the clay, it is coated with lead carbonate.

Opening No. 3 shows a vein of decayed rock, probably calcite, for a distance of 15 feet with a strike of N. 40 degrees W. Openings 2 and 3 extend only through the soil.

The shaft is 120 feet N. 40 degrees W. of opening No. 3. It is started from the bottom of a sink-hole 5 feet deep, and passes downward through clay filling a cavern from 2 to 6 feet wide. Eight feet above the top of the shaft is the Batesville sandstone, which occurs on both the north and south sides at the same level, showing that there is no faulting. No ore was taken from the shaft.

Opening No. 4 is a cut running N. 40 degrees W. The cut is 30 feet long, 10 feet deep and 3 feet wide. The cavern

is 10 inches wide and is filled with clay. At the bottom of the lower or outer end of the cut, a small amount of galena was found in limestone. The cavern at this place, and probably at the other point of development, is a joint enlarged by solution. This point is 20 feet lower than opening No. 1. No zinc was found. (A. H. Purdue, 1900.)

The Blue Bluff mine, formerly called the Jasper, is in 15 N., 22 W., section 1, southwest quarter of the northwest quarter. It is on the top of what is locally known as "the Blue Bluff" on the south side of Henson Creek, and is in the Boone chert.

The development consists of two shafts 30 feet apart, No. 1 being 40 feet deep, No. 2, 15 feet deep. Both contained water when the mine was visited in August, 1900. The ore is smithsonite (and calamine—Hopkins), with a small amount of zinc blende and some galena. The zinc occurs in brecciated chert, while the galena occurs as small crystals in the limestone of the shaft. The shafts are 200 feet above the creek to the east, and 300 feet above Henson Creek.

In the ravine 300 feet south of the shafts the chert dips 20 degrees S. 45 degrees E. Mr. Hopkins says a fault is shown on the face of the bluff with the downthrow of about 15 feet on the southeast side. (A. H. Purdue, 1900.)

The Big Tom claim is in 16 N., 22 W., section 36, the southwest quarter of the southeast quarter, and 300 feet above the Panther Creek claim. A shaft 39 feet deep penetrates the Boone chert after passing through 25 feet of clay and sandstone boulders, talus from the mountain. The bottom of the shaft is in broken chert and clay. Some cubes of galena and zinc silicate have been taken from the shaft. (T. C. Hopkins.)

The Boston claim is located in 16 N., 22 W., section 36, the southwest quarter of the southeast quarter. It is

Horizontal slickensides at the Panther Creek mines.

20 feet deep in the chert and cherty limestone and showed small quantities of galena.

The Panther Creek mines are on Panther Creek, a tributary of Henson Creek, which in turn enters Little Buffalo three miles south of Jasper, Newton County. They are in 16 N., 21 W., section 31, northwest of the northeast, at an elevation of 160 feet above Jasper. There are several openings, open cuts, shafts and tunnels, on the property. The rocks at the mines all belong to the Boone chert series and are nearly horizontal. At the mines, however, and for several hundred yards up Panther Creek northwest of the mines the rocks have a gentle (2 degrees to 3 degrees) dip to the southeast (about S. 30 degrees E.) —that is, toward the mine openings.

The most westerly openings are two cuts on opposite sides of Panther Creek channel and on a level with the creek bed. These openings are upon a break and fault in the rocks that lies N. 22 degreesE. (magnetic). The side of one of these open cuts is beautifully marked with horizontal slickensides. The accompanying plate (XIX) is from a photograph of one of these striated walls. The displacement of the rocks along this fault has been chiefly

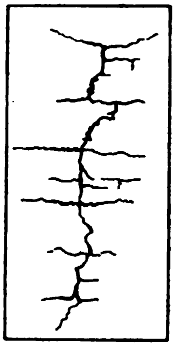


Fig. 48. Form of the ore on a section across he fault at the Panther Creek mines.

a lateral one. The cut on the north side of the hollow is 43 feet long, with an average width of six feet or a little

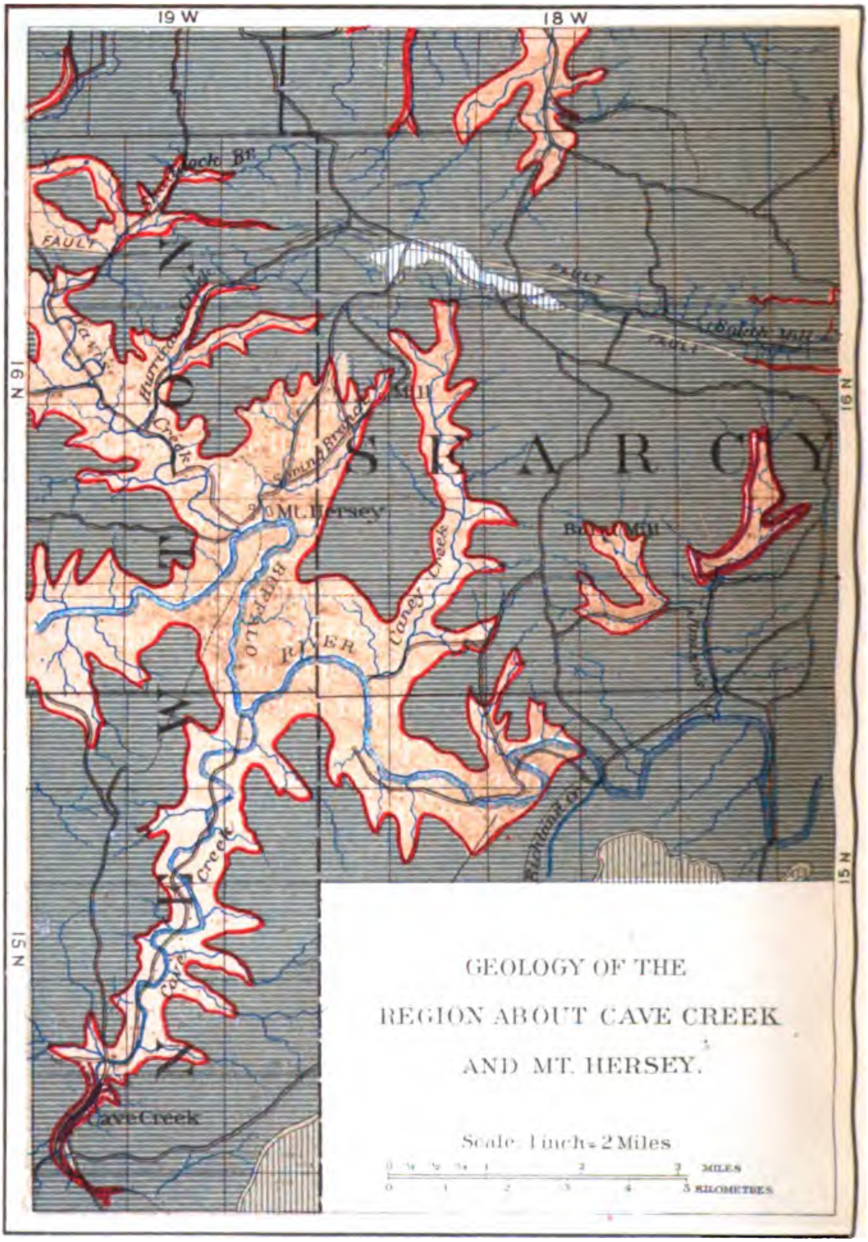
more. The ore in this part of the cut is mostly zinc blende deposited in the fracture, but running out also between the beds on both sides of it. The general form of the ore streaks in the face of this opening is shown in the accompanying cut. (Fig. 48.)

Some of the rocks, however, both in the cut and shaft are brecciated and the zinc blende has been deposited along with dolomite and calcite in the spaces between the angular fragments of limestone and chert. These veinlets are sometimes several inches across, and thin down to imperceptible films.

On the south side of the hollow is another cut seven feet wide, 12 feet deep, 17 feet open, and continued for 12 feet as a tunnel. This opening is on the continuation of the fracture followed by the cut on the opposite side of the hollow. The blende ores are found here in the form of veins and as crystals disseminated through the rock, and also in the form of zinc carbonate.

Sixty feet south 22 degrees west from the mouth of this last named tunnel and 20 feet above the bed of the hollow is a shaft about 75 feet deep from which both zinc blende and zinc carbonate have been taken.

The above mentioned openings are all on the fault line, which, at this place, bears N. 22 degrees E. (magnetic). Beautiful specimens of zinc blende, some of them weighing several hundred pounds and almost entirely free from gangue rock, have been taken from these mines. Occasionally cubes of galena are found in the gangue rock associated with the calcite and zinc blende. This zinc blende is of excellent quality, as is shown by the following chemical analysis:



JULIUS BIEN & CO. N.Y.

Analysis of sphalerite from the Panther Creek mines.
(628.)

Zinc, Zn	65.88 per cent.
Sulphur, S	32 30 per cent.
Iron, Fe	0.49 per cent.
Calcium, Ca	0.44 per cent.
Cadmium, Cd	0.26 per cent.
Magnesium, Mg	trace
	99.37

This zinc blende has more or less dolomite spar deposited with it. Some zinc carbonite is also found on this property.

About 300 feet southeast of the shaft of the Panther Creek mines is a stope driven in the hill southwest of Panther Creek. This slope bears S. 22 degrees W. (magnetic), The rocks taken from this stope contain lead ore (galena) and lead carbonate, but no zinc was seen.

The ground southeast of the mouth of the stope is apparently all decomposed to a red clay containing chert fragments; 125 feet east of the mouth of the stope is a shaft put down in this decomposed rock. It is not known what it yielded. Other prospects were examined in the vicinity of the Panther Creek openings, but they were of but little importance at the time of examination (July, 1900).

THE CAVE CREEK DISTRICT.

The Lead mines of the Granby Mining and Smelting Company, formerly owned by the Boston Mountain Mining and Smelting Company, are in 15 N., 19 W., section 35, a mile and a half southeast of Cave Creek post-office, Newton County, and a quarter of a mile north of east from Mr. D. Hill's house. A number of shafts, including the main one from which the greater part of the ore was taken, are on the point of a low hill from 20 to 30 feet high between two small ravines, secondary affluents of Cave Creek. Other apparently less productive shafts are north of these.

The ore occurs in the rocks of the Boone chert series, possibly near the top. The mouth of the main shaft is 190 feet above Cave Creek post-office, which is on top of the Ordovician; however, the rocks are so folded in this region that such a measurement signifies but little. Less than a quarter of a mile north of the main shaft the Batesville sandstone is exposed in the creek bed at but little elevation above the mouth of the main shaft, which would indicate the position of the ore to be near the top of the chert. It is possible, however, that there are faults between the shaft and the sandstones. There are some sandstone boulders on the surface, but all the rock on the dump is chert, comparatively free from limestone. Some of the chert is brecciated, and the zinc and lead ores form the cement. Galena, "dry bone," zinc blende and calamine are all found on the dump. Galena is the ore reported to have been taken out when the mines were in operation.

The mines were worked by the Boston Mining and Smelting Company in 1876 and 1877. A smelter was erected on the bank of Cave Creek a quarter of a mile south of the post-office where the ore was hauled and reduced to metallic lead. The pig lead was hauled by wagon to Russellville on the Little Rock and Fort Smith Railway and thence shipped to Pittsburg, Pennsylvania. The total product was not ascertained, but four or five teams were at work hauling the ore and metal for about one year.* (T. C. Hopkins.)

THE MOUNT HERSEY DISTRICT.

The prospects in the immediate vicinity of Mt. Hersey are all in Ordovician rocks. The exposures at which zinc has been found are not sufficient to disclose certainly the nature of the deposits. The prospectors are said to have

* The historical information was obtained from Mr. Richard Thompson, formerly postmaster at Cave Creek.

worked upon the theory of fault lines like those of the Big Buffalo and Henson Creek districts of Newton County. So far as can be judged without more work upon the geology of the district this assumption is without support, though the occurrence of slickensides on the Pratt property gives a little support to the fault theory. The fact that some of the rocks are brecciated cannot be regarded as evidence one way or the other, for breccias are not confined to faulted rocks though they are often found in regions of faults. In some of the openings at the Canady mines the rocks are certainly not faulted.

If upon further development it seems clear that the rocks of this district are faulted, it is only necessary to say that these faults are seldom or never perfectly straight lines, although they often follow approximately the same course for many miles. Further, the ore deposits along such faults are seldom of uniform richness, but they are liable to be rich at a few points and barren at others.

In Boone, Marion, Baxter, Sharp and Lawrence counties the zinc ores found in the Ordovician rocks are largely bedded deposits—that is, they are confined to certain sedimentary strata, and only occasionally appear in fractures. The occurrence of the zinc in these other counties suggests at least that in the Mt. Hersey district the ores are liable to be in approximately horizontal beds.

The Round Mountain claim was not examined by the writer. It was reported by a trustworthy authority to be located in 16 N., 19 W., section 23, northwest of the southwest quarter. The openings are a shaft 32 feet deep and a drift 8 feet long. The rocks passed through are Ordovician, and the zinc blende and zinc carbonate occur in vertical crevices just as they do in the Canady mines. Several other openings on the same property all show zinc carbonate and zinc blende.

The Canady mines are in 16 N., 19 W., section 24, the east half of the southeast quarter, about one mile northeast of the Mt. Hersey post-office in Newton County. The openings are in horizontal Ordovician limestones, dolomites, and sandstones, and consist of a shaft and several open pits.

The ores are zinc sulphide, carbonate and silicate. One of the pits, mostly in sandstone, is 15 feet deep, 10 feet long and six feet wide. The following sketches show the arrangement in vertical crevices of the zinc blende exposed on the face of the west side of this pit.

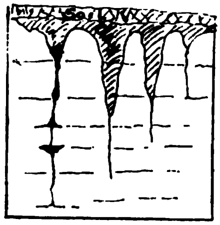


Fig. 49. The west wall (15 feet) of the Canaday showing zinc black) in vertical streaks.

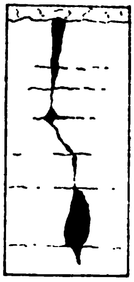


Fig. 50. Face of one of the Canaday pits with zinc carbonate in vertical crevices.

In some of the other pits some zinc was found while in still others none was found. The shaft is in clay, limestone and sandstone, and is 32 feet deep. There is a little zinc carbonate on the dump by the mouth of the shaft.

The Pratt outcrop is in 16 N., 19 W., section 24, southwest quarter of the southeast quarter on the east side of the Mt. Hersey-St. Joe road and on what was formerly

known as the land of the Wheeler heirs. It consists of a natural and partly uncovered ledge of Ordovician dolomite and sandstone containing a good deal of fine zinc carbonate and some zinc blende. This ledge bears N. 80 degrees E. and the ore is exposed over a width of about 75 feet. Slickensides was observed at one place in these rocks. The rocks at the openings are about 250 feet below the Carboniferous rocks which outcrop on the hill east of the prospects. Very little development work has been done so that the richness and extent of the ore on this property is unknown.

There is another prospect on the Pratt property in section 25, the northeast quarter of the northwest quarter and on the west side of Mill Branch.

The Mesplay shaft, as it was formally called, but on land of the Granby Mining and Smelting Company, is in 16 N., 19. W., section 24, the southwest quarter of the southwest quarter, on the west side of Mill Creek, in rocks of Ordovician age. The shaft is reported to have been sunk 90 feet, but not work has been done for many years and the shaft is now filled with debris. There are numerous fragments of zinc silicate and blende on the dump. (T. C. Hopkins, 1892.)

Lee prospects. On the farm of John Lee, a quarter of a mile north of Mt. Hersey post-office (16 N., 19 W., section 25) there are two shafts in the horizontal Ordovician rocks. One of these shafts is about 150 feet northwest of the dwelling house, and is 47 feet deep. It passes through sandstones and brecciated magnesian limestones. Another shaft within five feet of this one is only eight feet deep in clay. Considerable zinc carbonate, but no blende, was found in these shafts. A third shaft 100 feet northwest of the first mentioned one, and in the old road is 26 feet deep, but no ore was found in it.

NOTES ON THE REGION ABOUT ST. JOE.

Prospecting along the St. Joe Fault.—It will be seen by looking at the map accompanying this report that the fault spoken of in the text as the St. Joe fault is a very long one. It begins a mile and a half southeast of Pinnacle mountain and two miles west of Yardell, 16 N., 19 W., section 6, and runs a little south of east to the St. Joe mines. At this place it swings gradually northward past the Davy Crockett, crosses Tomahawk Creek in 17 N., 17 W., section 35, and from that point bears northeast to the headwaters of Little Rush Creek in section 2 or 3, 17 N., 16 W., possibly continuing still further to the northeast. Going back to 16 N., 18 W., it will be seen that across this township this is not the only fault, but that there is a parallel one from a quarter to three quarters of a mile south of the other, but not known to accompany the principal fault its entire length. The St. Joe fault is here spoken of as a single continuous fault. This is not known to be true, indeed it is highly probable that instead of a single continuous fault it is a series of more or less broken and probably overlapping faults. It is also improbable that this fault or set of faults has throughout the same amount of displacement as that found at the St. Joe zinc mines, namely, 283 feet.

The characteristics of this fault are not the same throughout its entire length. In some places the Carboniferous rocks—the St. Joe marble or the rocks of the Boone chert series—are let down until they abut against Silurian and Ordovician rocks. This is true of much of the country along the fault between the St. Joe mines and Rush Creek. But there are other places where the displacement has simply brought the upper part of the Boone chert down against beds at the base of the Boone chert series on the north or northwest side. At still others the overlying beds

have all been removed and Silurian and Ordovician rocks are exposed on both sides of the fault.

So far as zinc is concerned the problem of the accumulation of the zinc ores along this fault is by no means settled. It is not known at present and cannot be positively stated from anything shown by present developments whether the best deposits are to be sought directly on the fault or a little to one or the other side of it. And this is not a matter that can be determined by a single opening or prospect. It may be indeed that there is no rule that is applicable to the fault as a whole, but that there are all kinds of local variations in the character, position and amount of the ores.

The Big Hurricane mines are on the upper part of Hurricane Creek hollow in 16 N., 18 W., section 7(?). They are upon or near one of the two east-west faults that cross township 16 N., 18 W., from near the town of St. Joe in the direction of Yardell. The evidences of the fault in the vicinity of the mines are abundant and conclusive. This fault runs part of the way down the hollow in which the mines are located and then rises along the south facing hill-slope and passes Lewis' still-house. At the still-house which is near the top of a hill north of the hollow, the Ordovician sandstones are the surface rocks, while the dwelling house in the hollow to the south and at a much lower elevation is upon rocks of the Boone chert series. A big spring a short distance up the hollow from the house emerges from the Boone chert beds. Going northeast up the hollow from Lewis' house the road passes two shafts, the first 30 feet deep and the second 21 feet deep, both of them in the Boone chert, and consequently south of the fault line.

About three quarters of a mile above Lewis' house are the principal openings of the Big Hurricane mines. They are all on the south side and near the bottom of the valley.

Plate XXI is a view looking west down the hollow at some of the openings of this property.

It is scarcely necessary to describe these openings in detail. They are mostly open cuts and prospecting pits evidently made for the purpose of determining the character and extent of the ore rather than to develop the property. One of these cuts has a face 240 feet long and exposes zinc carbonate nearly this entire distance, much of it remarkably fine. The ore in all the openings is chiefly zinc carbonate (smithsonite) with which some zinc blende (sphalerite) is found. A shaft put down 25 feet deep on the hill above these open cuts has also struck the carbonate beds. At one place a stope has been started to follow down the dip of the ore-bearing chert beds. The dip here is 42 degrees.

These orders are all from the Boone chert series, some of them from clays formed by the decomposition of hard rocks, and some of them from crevices in the chert beds. The cuts already made and the general geology at these mines show that the ore face now uncovered is but a small part of the ore to be expected along the south face of the hill near the fault.

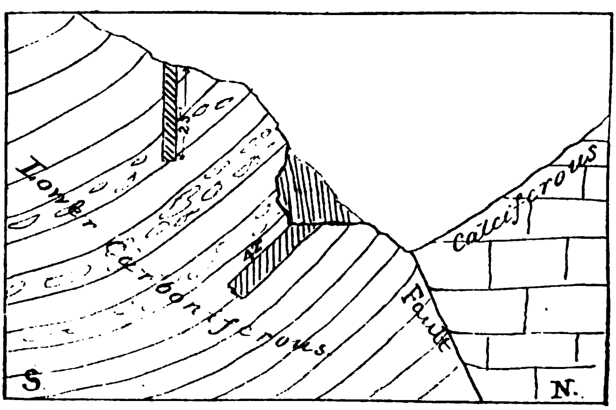


Fig. 51. Section at the Big Hurricane.

These openings are all on the south side of the fault. Whether the fault itself will yield any considerable amount

Looking west at the openings along the Big Hurricane fault.

Looking up Monkey Run near the St. Joe fault; a characteristic bit of topography.

of ore can only be determined by prospecting. The above sketch shows the geologic structure. It will be seen that the fault is close to the gully. The amount of displacement was not determined, but Professor Purdue thinks the Boone chert on the north side of the gulch is only about a hundred feet above the bottom of the gully. The upturning of the Boone chert beds at the openings suggests that the fault face dips toward the south.

The St. Joe mines are on Monkey Run, in 16 N., 17 W., sections 7, 8 and 18. (See plate XXII.) They are all either upon or close to the St. Joe fault that passes through these sections in a direction a little south of west and north of east. This fault is of so much importance not only in connection with the prospects already opened upon it, but for future prospectors, that it is here described in more than usual detail.

The town of St. Joe stands upon the Batesville sandstone, which at this place is somewhat calcareous. These beds dip northward—up the stream that flows through the town. Going up the stream toward the mines one finds very black shales—called by the writer the Marshall shale on account of their occurrence near the town of Marshall, Searcy County. These shales are well exposed at the site of the old mill and gin on the right side of the creek. A little north of the old mill there are fragments of the Batesville sandstone again, and still further on the rocks of the Boone chert series appear, dipping toward the south. The sequence of these rocks shows that there is a syncline or trough-like fold at the old mill site. Passing on upstream toward the mines one crosses the total thickness of the Boone chert series and at the crossing of the stream finds the St. Joe pink marble that lies at the bottom of this series exposed in an overhanging bluff and dipping south at a high angle. A little further north the St. Joe marble is beautifully exposed in a bluff on the east side of the val-

ley. Above the St. Joe the Boone chert series is well exposed, and below it is a bed of phosphate rock 3 or 4 feet thick filling the gap between the Carboniferous (St. Joe) rocks and the Silurian marble (St. Clair) in the bed of the creek at this place.

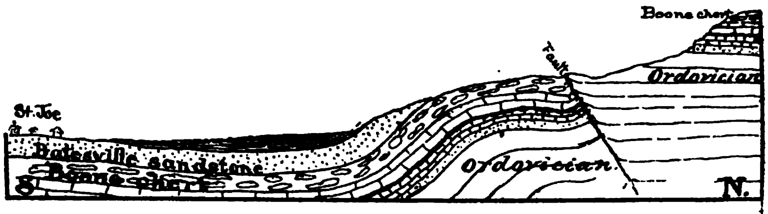


Fig. 52. Section across the St. Joe fault.

Proceeding northward up the creek one passes over Silurian and Ordovician rocks until the large spring is reached near the zinc mines. This spring issues from the level of the saccharoidal sandstone in the Silurian rocks. North of this spring it is evident that the rocks belong to the Ordovician, but they belong below the saccharoidal sandstone, which is left behind in the bottom of the gulch at the spring. The mountain north of the mines is of horizontal Ordovician rocks up to a certain point where the St. Joe marble and the Boone chert beds cap the ridge. A line of levels run from the top of the saccharoidal sandstone at the spring in the valley to the top of the same bed on the mountain slope to the north shows that the throw of this fault is 283 feet.

The position of this fault is easily determined by the distribution of chert fragments over the surface of the ground. In the accompanying cross section of the fault it is seen that Boone chert is at the surface on the south side of the fault while north of this line the Silurian rocks are at the surface. Those familiar with the Boone chert know that when exposed it breaks up into small white angular fragments that thickly cover the ground. Along this fault

The siliceous ledge along the St. Joe fault above the Dale shaft, near St. Joe.

line the angular chert of flint fragments strew the ground south of the fault, but they end abruptly at this break. At some places along this fault there are rough jagged rocks from 4 to 10 feet wide and rising from 2 or 3 to 10 or 20 feet above the general level of the ground. Plate XXIII shows some of these peculiar rocks on the St. Joe fault near one of the old shafts on the Garvin & Lombard property. These masses are usually very hard siliceous breccias apparently the more resisting portions that filled the fractured zone of the fault; they have been left in relief by the weathering and removal of the adjacent wall rocks.

The ores found in the openings at the St. Joe mines are both smithsonite (zinc carbonate) and sphalerite (zinc sulphide). The carbonate is found mostly near the surface in the decomposed and altered rocks while the sulphides are found chiefly in the unweathered rocks and in the deeper openings.

What is known as one of the Dale shafts is thirty feet deep and seems to be on the fault. The rocks on the north and south sides are approximately horizontal, and a

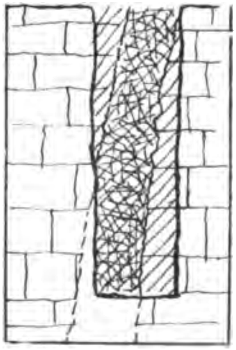


Fig. 58. Section through a shaft on the St. Joe fault.

crushed zone having a width of 6 or 7 feet is exposed in the walls.

Some zinc carbonate and some zinc blende are said to have been taken from this opening; it is worthy of note

that though this shaft was directly on the fault les sore was found in it than in some of the openings that were not directly upon the break.

The same thing is true of the deep shaft put down by Colonel Dale on top of the hill above the shaft house. This shaft is 6 by 8 feet in the clear, 90 feet deep, and is directly upon the fault. For a depth of 30 feet this shaft is without timbers and the structure is fairly well exposed. It is said that comparatively little zinc ore was found in this shaft.

These old shafts have been abandoned, and two later ones put down close to but not upon the fault. One of these—the Garvin shaft—is 38 feet deep, is in unweathered dolomite as shown by chemical examination and the ore is all zinc blende except a little carbonate found near the surface. A chemical examination of the rock from the 38-foot shaft shows it to be a dolomite. An average sample of the zinc blende from this shaft was also analyzed.

Analysis of sphalerite from the Garvin shaft, St. Joe.

Zinc, Zn	65.73 per cent.
Sulpher, S	32.92 per cent.
Silica, SiO_2	0.11 per cent.
Iron, Fe	0.15 per cent.
Magnesia, Mg	0.08 per cent.
Calcium, Ca	0.50 per cent.
Cadmium, Cd	trace
	99.49 per cent.

Another large and well-timbered shaft called "th Excelsior," is 60 feet deep and the ore is practically all zinc blende in breccia. This shaft goes below the water level and when worked requires much pumping. In order to make room for an engine house over the Excelsior shaft the country rock on the side of the hill was blasted away. This rock is full of veinlets of zinc blende, most of them standing vertically, but some of them cementing brecciated quartzose rock.

The openings of the Excelsior and Garvin claims on the St. Joe fault show the necessity of determining in this district whether the richest deposits of zinc ores are to be expected directly upon the fault or a little way from the fault, and in case they are off the fault, on which side they are more liable to be found.

The direction of the throw of the fault, the folded condition of the Carboniferous beds and the upturning of both sets of beds on the fault line all suggest that the fault face dips toward the north. This will be understood by referring to the accompanying ideal section across the fault. It will be seen that if the two ends of this section were pressed together (and the wrinkling of the beds on the south side suggest that they have been so pressed) the beds on the north side would slide over those on the south side, and that in this movement the ends of the Carboniferous beds would be dragged upward on the ends while the Ordovician beds would be bent up like the ends of sled-runners, as they are really found.

These seem to be the main features of the St. Joe fault, though there are doubtless local variations in its character. Whether there are large bodies of ore on or near this fault can be best determined by drifts driven at right angles to the fault plane. Judging from what may be inferred from observations at other places, the ores are more likely to be on the northwest than on the southeast side of this fault. The geological structure and the occurrence of the ores at the *Davy Crockett claim* seem to throw some light upon the St. Joe fault.

The Davy Crockett property is in 16 N., 17 W., section 9, north half of the northeast quarter and the southeast of the same quarter; likewise the northwest of the northwest of section 10. The rocks in which the zinc occurs are Silurian. The geological structure will be understood from the following section drawn northwest-southeast

through the open cut or quarry and across the fault near at hand.

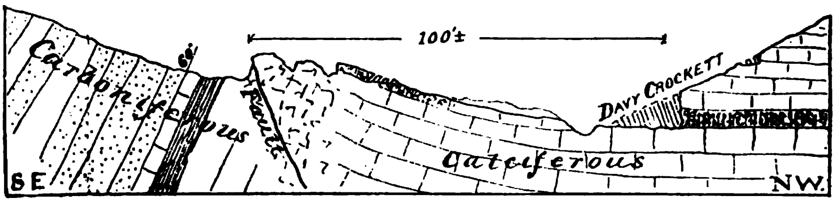


Fig. 54. Section at the Davy Crockett, near St. Joe.

The rocks on the hillside southeast of the quarry are Carboniferous shales (probably the Marshall shale) dipping due south at an angle of 63 degrees; these are followed in ascending order by limestones and sandstones (probably the Batesville sandstone) also dipping south at a high angle. The position of the fault is marked by a wall of hard siliceous, more or less broken Silurian rocks, blocks of which mark the face of the fault toward the northeast. A short distance northwest of the fault somewhat brecciated Silurian rocks are oxposed in a prospecting pit showing a gentle dip toward the northwest. These rocks contain a little zinc blende.

Northwest of the fault about 100 feet is the bed of the Younger Hollow branch of Tomahawk creek, and the open cut or prospect quarry is opened on the left or northwest side of the hollow in Silurian beds.

The rocks are mostly sandstones, but there are some limestones. The open quarry has a face from 7 to 9 feet high, from 12 to 20 feet wide at the bottom and 75 feet long.

The ore is zinc blende in veins cutting the bottom 6-foot bed. Whether it goes deeper is not shown in the cut. The beds are nearly horizontal, but have a gentle dip to the southeast. The blende fills crevices in this bed and runs in every direction. Some of the veinlets are six inches wide and 4 or 5 feet long.

It will be seen from the section made across the fault at the Davy Crockett that the geology is very similar to that at the Excelsior and Garvin mines on Monkey Run at St. Joe. The Carboniferous rocks have been pressed up against the Silurian beds and a northwest dipping fault face has caused the ends of the Silurian beds to bend up gently near the fault.

The occurrence of considerable zinc ore a hundred feet away from the fault in Silurian rocks, where they form this gentle fold is a striking feature of this locality. The rocks directly upon the fault have not been prospected here, but the chances are that they have not been, because the prospectors did not find zinc enough in them to warrant exploration. But until a tunnel is driven entirely across this fault the location of the main ore body will not be known with certainty.

The Roaring Hollow prospects are in 16 N., 17 W., section 8, on the St. Joe fault. The rocks on the southeast side of the fault are Carboniferous and belong to the Boone chert series, while on the northwest side they are Silurian beds.

The St. Joe marble and Boone chert beds here dip 62 degrees S. 70 degrees E. Only a few small pits have been dug (July 6, 1900), some in the Silurian and some in the Carboniferous beds. Zinc blende closely resembling that at the Excelsior shaft is found in Silurian breccias in openings near the fault.

The Mud Hollow claim is in 15 N., 16 W., section 15, northwest quarter, on a tributary of Tomahawk Creek known as Mud Spring Branch.

The openings are cuts made on the east side of the hollow in horizontal Ordovician rocks. One at the miners' cabin is 8 feet wide, 10 feet long and 9 feet deep. Some zinc blende, a little copper silicate and some chalcopyrite were found in this opening.

Another opening about 800 feet south of the cabin and 20 feet above the floor of the hollow exposes brecciated siliceous rocks cemented with dolomite spar and some zinc blende.

The geology down the hollow from the mines shows that the rocks are either faulted or very sharply folded between the openings and the mouth of the Mud Spring Branch. About the south end of the hollow the hillsides are covered with broken fragments of the Boone chert; as one goes north, up the hollow toward the mines, he sees the St. Joe marble bed in the bottom of the creek. Continuing up the hollow one finds the Silurian rocks forming the slopes of the hills, showing that they have here been lifted to the level of the Boone chert beds about the mouth of the hollow. The mine openings are several thousand feet from the fault.

NOTES ON THE YELLVILLE VICINITY.

The Little Rock mines are on the north side of Hall Mountain in 18 N., 15 W., section 7, west half of the southeast and the east half of the southwest. The openings are high up on the mountain side in rocks of Ordovician age. The red St. Joe marble of the Carboniferous crops out on

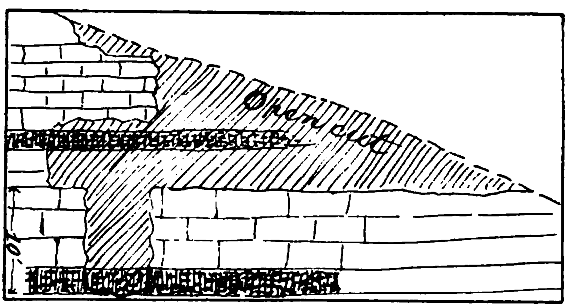


Fig. 55. Section at the Little Rock openings showing the bedded ores.

the slopes and runs around the mountain-top about 150 feet above the openings. The rocks are nearly horizontal dolomites, cherts and breccias.

The ores are carbonates near the surface in the earthy rock coverings, and zinc blende in the unweathered parts of the beds, both near the surface and where they have been opened upon. (Fig. 55.)

The ores follow the horizontal beds as shown in the accompanying sketch which represents the development when this property was examined (July 10, 1900).

It is worthy of note that there are here two beds of ore-bearing rocks about 14 feet apart; the upper bed is 2 feet thick and the lower one 3 feet thick as far as uncovered.

The winze sunk at the end of the open cut does not pass entirely through the ore-bearing bed in the bottom so that it is not known whether or not this bed is thicker.

Additional information regarding the geology of the Little Rock mines is had at the prospects opened on the west side of the Schley claim that joins the Little Rock on the west.

An interesting feature of the ore found at this place is the laminated condition of much of it. Locally it is known as "layer cake" ore, a name that forcibly expresses its appearance. When the ore is in the form of sphalerite it may be regarded as typical of the bedded ores. The ac-

Fig. 56. "Layer-cake" ore from the Little Rock. Natural size.

companying cut shows this interbedding of sphalerite and chert. The manner in which the bedding planes pass around the crystals of zinc suggests that these crystals were enlarged before the beds were hardened. It is not an

uncommon thing to find zinc blende interbedded with thinly laminated sediments, but at the Little Rock claim much of it is smithsonite that is thus interbedded with the gangue rock. It is an interesting illustration of the alteration *in place* of sphalerite or zinc blende to smithsonite or zinc carbonate.

The Schley claim is in 18 N., 15 W., section 7, west half of the southwest quarter, joining the Little Rock claim on the west. The geology is about the same as that of the Little Rock property, namely, horizontal Ordovician rocks 150 feet below the red St. Joe marble on the north side of Hall Mountain. The opening is a pit about twelve feet deep in siliceous dolomites containing zinc blende and zinc carbonate. The ore-bearing bed exposed is 2 feet 4 inches thick.

The Lost Jack mines are in 18 N., 16 W., section 12, southeast quarter, high on the west side of Hall's Mountain. The openings are all in horizontal Ordovician rocks —siliceous dolomites, cherts, and quartzites. The openings are chiefly open cuts exposing faces from 50 to 75 feet in length, and one tunnel 22 feet long.

The ores are zinc carbonate and zinc sulphide. The blende is exposed in the cuts in a bed having ten inches of rich ore. In the tunnel the ore-bearing bed is 5 feet

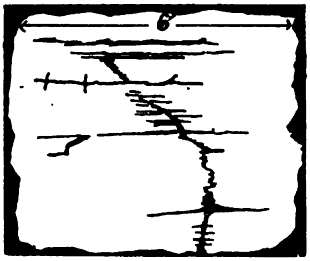


Fig. 57. Section of the face of a drift at the Lost Jack, showing the ore in crevices and bedding planes.

thick. The face of the drift shows the zinc blende following both horizontal and vertical planes, as shown in the above diagram.

Figure 58 shows another synclinal fold on the south side of and close to Rush Creek. This syncline carries the ore-bearing chert bed below the level of the valley, but at some points it does not lie very deep. For example, in the hollow entering Rush Creek Valley from the south between the Morning Star and the McIntosh, the saccharoidal sandstone ledge is at a considerable elevation, perhaps 50 feet, above the level of the valley. The zinc-bearing chert is about 100 feet below the base of this great sandstone, so that one can readily determine, by measuring on the north side of the valley the distance of the ore bed below the saccharoidal sandstone, just how far he would have to go in the valley in order to reach the zinc deposits. In the hollow south of Rush Creek and opposite the post-office the folded St. Joe marble is exposed. A shaft put down in the middle of this syncline would reach the zinc-bearing chert at a depth of about 175 feet. If the shaft were sunk either further up or further down this side hollow the depth to the zinc bed would be less, but the position would not be so favorable for mining. Mines in this cyncline, however, are liable to be very wet.

It must not be assumed, however, that the section across Rush Creek valley is everywhere the same. Half a mile further up or down the valley the section will be found quite different in details from that given under the description of the Morning Star mines.

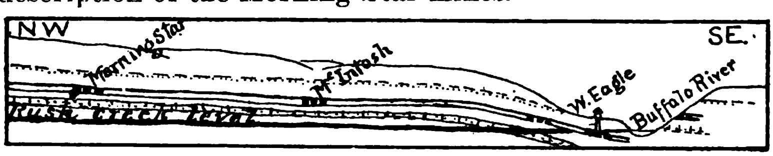


Fig. 59. Section along Rush Creek, showing the eastward depth of the zinc-bearing bed.

There are fracture and vein deposits in the Morning Star, McIntosh and White Eagle mines, but these mines are all located on the same ore bed. The same bed is ex-

Entrance to the Climax tunnel.

posed at the Silver Hollow and the Red Cloud properties on the opposite side of Buffalo River, apparently brought up by a small fault. The position of the throw of the fault suggests that the face of the fault dips toward the southeast—a matter that may be worth investigating by the owners on the right side of Buffalo.

The Climax mine is on Little Rush Creek in 17 N., 16 W., section 1, southwest quarter of the northeast quarter.

The ore-bearing rocks are of Ordovician age, but the geology in the vicinity is rather unusual for this part of the state. Two thousand seven hundred feet below (down the hollow from) the Climax tunnel the narrow V-shaped valley forks, the other branch from the north joining this one from the south. Where these hollows unite, the red St. Joe marble is exposed. Up the hollow from this point toward the Climax the Boone chert is exposed in the bottom of the valley to within 230 feet of the Climax tunnel. At this point, without any St. Joe marble being exposed, the Calciferous (Ordovician) beds are the surface rocks, and the Carboniferous cherts with the saccharoidal sandstone beneath are exposed 80 feet up on the southeast side of the hollow. In the bottom of the hollow the Calciferous rocks continue to and beyond the mine openings. At the mine the rocks have a gentle north dip and the saccharoidal sandstone (Ordovician) is 40 or 50 feet above the tunnel while the Boone chert caps the hilltops above.

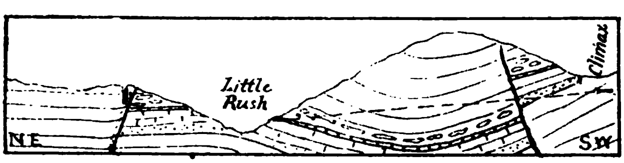


Fig. 60. Geologic section near the Climax showing the syncline and double fault

These facts appear to point to a fault about 600 feet down the hollow from the Climax tunnel. If this conclusion is correct the downthrow of the fault is on the north

side and the displacement is between 50 and 75 feet. The probable structure is shown by Fig. 60.

The principal openings are in the bottom of the hollow and consist of two open cuts, one of which is continued as a tunnel 26 feet long. The ore is mostly confined to two beds. These ore beds are exposed for about 60 feet. The rich places in these beds vary in thickness up to 2 feet, but mostly follow the bedding planes. One of the gangue

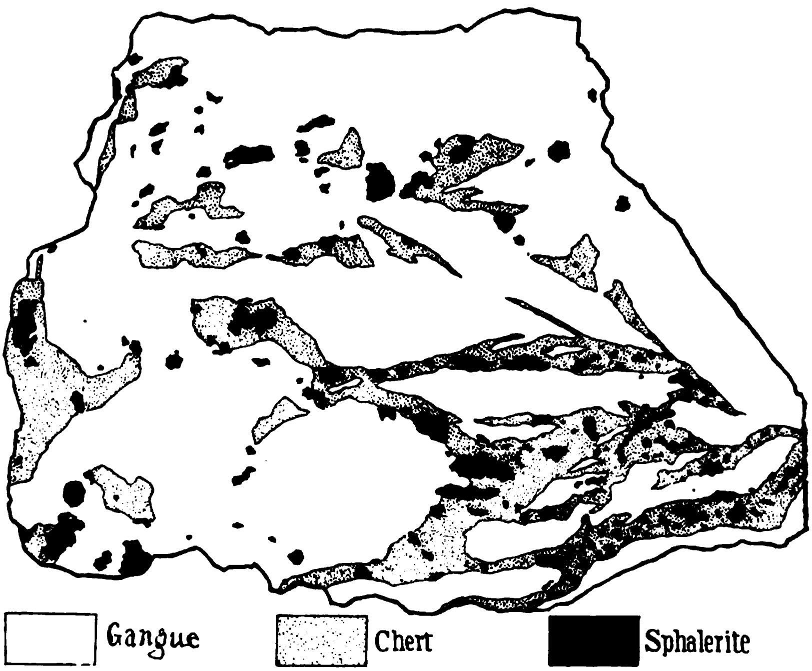


Fig. 61. Brecciated zinc ore in a gangue of chert and amorphous silica, natural size; from the Climax tunnel.

rocks is a bluish shale or clay-like rock, much brecciated and having the zinc blende disseminated through streaks of chert that penetrate the clay-like bed. The accompanying cut shows the form of this ore. A chemical analysis was made of the gangue rock with the following results:

Analysis of the clay-like gangue rock of the Climax tunnel.

Silica, SiO_2	83.51 per cent.
Iron and Alumina, Fe_2O_3 and Al_2O_3	11.87 per cent.
Magnesia, MgO	trace
Lime, CaO	0.51 per cent.
Sulphide of zinc, ZnS	0.81 per cent.
Oxide of zinc, ZnO	0.61 per cent.
Phosphoric acid, P_2O_5	0.26 per cent.
Oxide of Manganese, MnO	trace
Loss on Ignition, H_2O	2.79 per cent.
	99.86 per cent.
Hygroscopic water	1.89 per cent.

The following is a section of the side of one of the cuts:

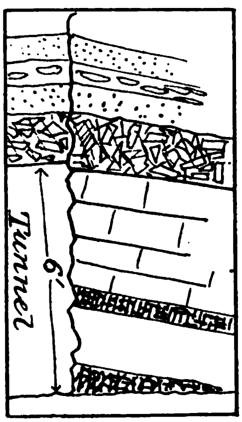


Fig. 62. Section at the mouth of the Climax tunnel. The shaded beds near the bottom are ore-bearing.

The following shows the distribution of zinc blende in the face of the tunnel July 11, 1900:

Fig. 63. An exposure on the wall of the Climax tunnel showing the distribution of zinc blende (black) in chert gangue.

If the writer's theory regarding the zinc ores in this region is correct, the most promising place to seek it in this locality is at the bottom of the synclinal fold about 1500 feet down the hollow from the Climax tunnel. Unfortunately for this place the ore-bearing horizon is carried down partly by the fold and partly by the fault so that it now lies at a depth of 300 or 400 feet below the bottom of the hollow. And mines at this place would have much water to pump.

Before further prospecting is done here the geology ought to be worked out in careful details; the above notes must be regarded, not as settling the matter of the geological structure, but merely as a suggestion based upon a hasty reconnaissance.

Additional light is thrown upon the geology northeast of the Climax by that of the hill on the northeast of the northeast of section 1 (17 N., 16 W.). This hill stands in front of the mouth of the hollow in which the Climax is located. It is capped by St. Joe marble on the west side, but along the east side of this quarter Ordovician rocks are at the surface and a fault crosses the hill bearing S. 30 degrees E. A shaft being put down a few feet east of the fault shows the rocks more or less broken and crushed and found some zinc blende in brecciated chert and quartzite. (See Fig. 60.)

The Creek dig near Maryhattiana is on Cold Water Branch in 17 N., 16 W., section 12, southeast quarter of the southeast quarter. The hollow through which Cold Water Branch runs is a narrow V-shaped valley cut in Ordovician rocks, but with Boone chert capping the hills on both sides of the stream. The openings are in the bottom of the creek, and the zinc ore is found in certain beds that are especially rich in the basin of a small synclinal fold. The accompanying plate (XXVI), made from a photograph taken July 11, 1900, will give some idea of the structural

The synclinal fold at the Creek Dig, Maryhattiana.

Brecciated siliceous dolomite at the Creek Dig, Maryhattiana.

relations of the ore. A few yards to the right of the rocks shown in this plate is a brecciated mass shown in plate XXVII.

The lower parts of the zinc-bearing beds go below the water at this opening and could not be seen when this locality was visited July 11-12, 1900.

The relation of the zinc blende to the structural geology at this place is interesting and instructive, and seems to throw a useful light on the zinc geology of north Arkansas.

On the east or downstream side of the fold the dip of the rocksis 27 degrees S., 35 degrees W.; 25 feet to the west or upstream these beds dip 18 degrees N., 15 degrees E. Both up- and downstream from this place the beds dip toward this syncline; how far this continues I do not know. The ledges exposed in the hilltops above the mines also show the rocks to be somewhat folded. It is worthy of note that the richest portions of the ore-bearing beds follow the strike of the beds into the hill on the west side of the hollow, along the axis of this syncline. The rocks in the creek bed at this place are all veined with dolomite spar and zinc blende. At one point shown in the sketch the bottom of this syncline is somewhat brecciated and this breccia follows the strike of the beds. The mass of breccia shown in plate XXVII has its fragments cemented with dolomite and zinc blende. It is noticeable that a bed overlying the breccia is but little or not at all disturbed.

The Hill Dig, near Maryhattiana, is on Cold Water Branch in 17 N., 16 W., section 12, southeast quarter of the southeast quarter. It is on the west side of the valley above the Creek Dig and about 100 feet above the stream.

The openings are an open cut, exposing a face 20 feet high in the back and a shaft 22 feet deep sunk from the floor of the cut. The rocks are of the Ordovician series slightly tilted and broken by a small fault passing across

the shaft in the direction N. 55 degrees W. The vertical displacement of this fault is only one foot. There seems to be a vein on this fault from 8 inches to 2 feet wide. The material filling this fracture is somewhat broken and porous, as if it had been leached of much of its former mineral filling. The rocks adjoining the fracture are sandstones, quartzites and fetid limestones. South of the break they dip 14 degrees N. 15 degrees to 18 degrees E. On the north side of the break the dip is somewhat steeper. Zinc blende was found in the shaft sunk on the fracture all the way to the bottom.

Plate XXVIII is from a photograph of the rocks in place exposed south of the shaft. These rock faces are uncovered by stripping away the soil and clay and leaving the natural etched surface. This photograph shows the dip of the Ordovician sediments and also the joints filled with dolomite spar crossing the beds, now left in relief by the decomposition of the surrounding rock. Mr. Webber, the owner of this property, tells me that these dolomite veinlets often contain crystals of zinc blende.

The Morning Star mines are the best known and most talked about zinc property in north Arkansas. The land belonging to the company is sid to lie in several sections, but the main body of it is in 17 N., 15 W., section 10, the northwest quarter.

The mines are on the left or north side of Rush Creek and 150 feet above the bed of that stream. The main features of the geology of the hill will be understood from figure 59, given on page 184.

On the south side of Rush Creek the red St. Joe marble and the limestones below it are exposed in some of the side hollows dipping toward Rush Creek and nearly 300 feet lower than the outcrops of the same beds on the north side of the creek.

Etched dolomite with veinlets in relief on the joints, Hill Dig, Maryhattiana.

When I first examined the geology of this locality (July 13, 1889) I concluded that there was a fault approximately along Rush Creek Valley with the downthrow on the south side. Later observations have lead me to modify this opinion to a certain extent. The rocks have been folded, forming a deep syncline or trough along the axis of the valley; there are, however, several small faults parallel with the fold and having their downthrow on the south side. These small faults are found in all the mines along the hill between Rush Creek and Clabber Creek, and are mentioned in the descriptions of the Morning Star, the McIntosh, the White Eagle, and Silver Hollow properties. The apparent displacement of the rocks on the two sides of the creek is due therefore partly to faulting and partly to folding.

The zinc blende ore on the Morning Star property occurs both in approximately horizontal beds and in fractures or fissures. The disseminated ore is mostly in chert but sometimes in dolomite. Where fractures cross the beds of chert and dolomite they are filled with either dolomite spar or with zinc blende or with some combination of these two. And it often happens that the beds adjacent to these fractures contain more or less zinc blende while further away the same beds contain but little or no zinc.

The accompanying cuts, p. 192, illustrate this arrangement of the ore next to such fractures.

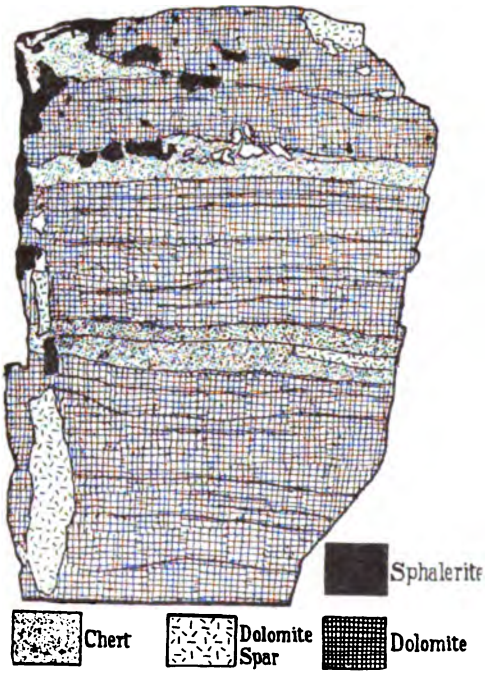


Fig. 64. Zinc blende in beds of dolomite and chert and in veins across the beds. Morning Star mine.

Fig. 65. Zinc blende in chert near a fracture across the bedding. Natural size; from the Morning Star mines.

Open cut at the head of the slope, Morning Star mines.

The zinc carbonate for which this mine is famous follows the blende deposits. It forms along the outcrop of the ore-bearing bed and along the weathered exposure of the fissure in which the blende is found. The depth to which weathering has extended varies greatly so that in places the blende is at or near the surface, while in others the carbonate is found in clays in crevices at a great depth beneath.

The openings consist of a number of open cuts, some of them quite large, shafts and tunnels which it is hardly necessary to describe in detail. These openings are on or near the ore-bearing beds and follow along the face of the hill. Plate XXX shows the open cut near the head of the track on the slope down which the cars carry the ore to the crushers. On the right the beds are horizontal, but on the left their bending is evident. The ore-bearing beds here are from 6 to 7 feet thick, with limestone beds 12 feet thick beneath them.

The Morning Star open cut No. 2 is at nearly the same elevation as that at the head of the slope and in it begin the horizontal Silurian beds. A portion of this opening is shown in Plate XXXI. This cut, or parts of it, follows a break in the rocks. The small fault mentioned below runs into this break, but it is not evident upon a hasty inspection whether or not there is in addition a considerable vertical displacement of the rocks. The broken gap between the apparently undisturbed walls is about 35 feet wide and this is filled to a depth of from 30 to 50 feet with decomposed rocks, tallow clay and zinc carbonate. Probably the finest masses of smithsonite ever found have been taken from this place.

At the lower left corner of plate XXXI is shown the opening into a chamber that has been stoped out of the rocks on the north side of this open cut. This chamber is 40 feet long by 35 feet wide by 17 feet high. In this the

ore is zinc blende mostly in two flinty beds each 2 feet thick and separated by 3 feet of barren rock, which is here and there cut across by vertical gash veins filled with zinc

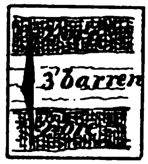


Fig. 66. Two ore beds in the Morning Star mine connected by a vein of later age.

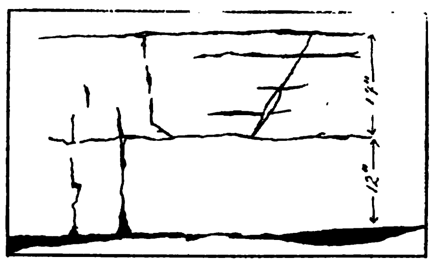


Fig. 67. Section in the Morning Star mines showing the zinc blende deposited along bedding planes and also in veins crossing the beds.

blende. The zinc ore in the beds is disseminated along the bedding planes, but it is richer here and there in lenticular bunches and sometimes it is more abundant near vertical crevices or breaks that are now filled with and cemented by zinc blende.

The rocks in this chamber have a gentle (one to two degrees) dip northward. As the fault in the open cut is approached in the south side of the tunnel the beds are not so rich in zinc.

At the northwest end of the open cut a small opening at the top of the quarry shows a nearly vertical fault with the downthrow of 3½ feet on the south side. The strike of this little fault is S. 7 degrees E. It runs into or toward the mouth of the big tunnel shown in plate XXXI. On the north face of the open cut and at the top the zinc ores appear to have a thickness of about 8 feet, mostly carbonate

Open cut and drift on the fractured zone at the Morning Star mines.

at the top and blende at the base. This great apparent thickness might appear to be exceptional, but it is due to

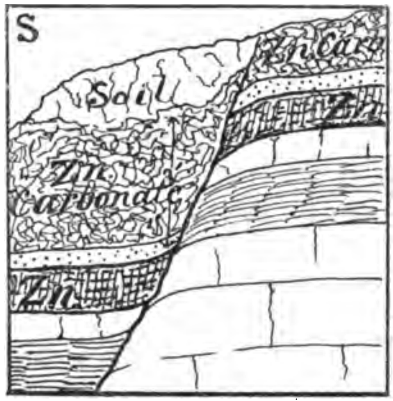


Fig. 68. A normal fault at the Morning Star mines showing a displacement of three feet.

the fact that the true thickness of the ore bed is repeated by the fault just mentioned.

East of opening No. 2 is a tunnel 70 feet long driven in the hill apparently for the purpose of striking the great carbonate vein. The rocks in the tunnel are banded siliceous dolomites, some sandstones and cherts, all dipping very greatly toward the north.

The most striking feature of the Morning Star mine is the abundance and purity of the smithsonite found there.

Analysis of smithsonite from the Morning Star mines

(645.)

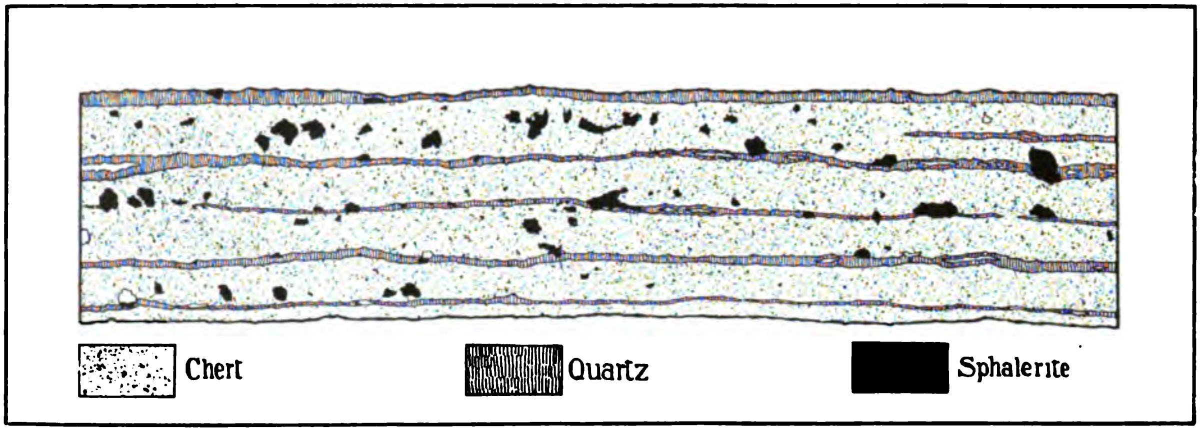
Zinc oxide, Zno	64.31 per cent.
Carbon dioxide, CO_2	34.93 per cent.
Water, H_2O	0.58 per cent.
Magnesia, MgO	.03 per cent.
Magnesia, MgO	.90 per cent.
Iron and Alumina, Fe_2O_3; Al_2O_3	0.12 per cent.
Sulphuric acid, SO_3	trace
Cadmium, Cd	trace
	100.87 per cent.

The zinc oxide in this material is equivalent to 51.61 per cent. of metallic zinc.

The smithsonite, however, is not always so pure. It often forms a light brown or yellowish earthy-looking coating upon the rocks or occurs as broken plates scattered through clay. One specimen of this spongy brown carbonate upon analysis gave 43.08 per cent. of metallic zinc; another gave 47.11 per cent. Analysis of a thick crust of white smithsonite showed it to contain the equivalent of 47.88 per cent of metallic zinc.

It may be worthy of mention that the theory that zinc carbonate may be deposited at a considerable distance from the zinc sulphide from which it is derived finds little or no support in the observations made at the Morning Star. The smithsonite is confined closely to the outcrop of the bedded deposit of zinc blende or to the break shown in plate XXXI.

An observation of interest in this connection was made upon a face of zinc blende that has been exposed for ten years in one of the old open cuts. Here I found the surface of the zinc specked with small crystals of zinc carbonate forming in place upon the blende from which it was apparently derived. It is a very common thing in this region to find crystals of blende completely coated with smithsonite. The bedded zinc blende found on this property is for the most part very like that found over a large portion of Marion County. A certain kind of ore-bearing, sedimentary, siliceous rock found here, however, appears to have undergone rather unusual alterations. Plate XXXII is drawn from a piece of this rock, but it is not possible to show satisfactorily in a line drawing the nature of the rock and the relations of the crystals of zinc blende to its other constituents. The horizontal bands are all of siliceous materials. Some of them are thin double bands of quartz crystals pointing upward and downward. Crys-



Altered siliceous rock with zinc blende and quartz, Morning Star mines; natural size.

tals of zinc blende are sparingly mingled with the quartz showing the two to have been deposited at the same time.

In other layers the siliceous material contains sphalerite crystals surrounded by quartzitic material—possibly of a cherty nature. In many instances the blende crystals have been dissolved out and the smooth inner walls of the cavities thus formed are lined with zinc carbonate.

A peculiar kind of smithsonite popularly known as "turkey fat," has been found in abundance in the Morning Star mines. It is of a beautiful lemon or sulphur yellow

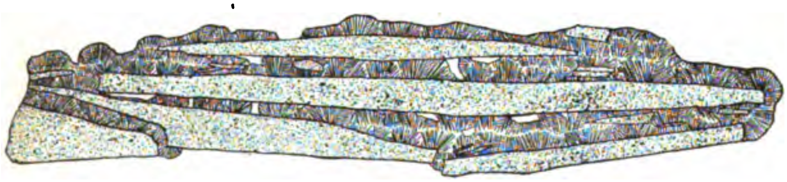


Fig. 69. Yellow smithsonite (radiate) formed in crevices in the chert. Natural size; Morning Star mine.

color and usually occurs as stalactites or incrustations. The yellow color seems to be due to the presence of cadmium. Chemical examinations of several specimens of this yellow smithsonite invariably showed it to contain nearly 1 per cent. of cadmium sulphide.

The accompanying illustration (Fig. 69), shows it filling the spaces between plates of chert.

Analysis of "turkey fat" (smithsonite) from the Morning Star mine.

Zinc oxide, ZnO	63.84 per cent.
Carbon dioxide, CO_2	34.60 per cent.
Water, H_2O	1.09 per cent.
Silica, SiO_2	0.25 per cent.
Magnesia, MgO	0.07 per cent.
Lime, CaO	0.70 per cent.
Cadium oxide, CdO	0.90 per cent.
Iron and Alumina, Fe_2O_3; Al_2O_3	0.42 per cent,
Manganese, MnO	trace
	101.87 per cent.

The zinc oxide in the above specimen is equivalent to 51.23 per cent. metallic zinc.

Another partial analysis of "turkey fat" (smithsonite) from the Morning Star mine gaye the following results:

Zinc, Zn	49.11 per cent.
Sulphur, S	0.43 per cent.
Cadium, Cd	0.82 per cent.
Iron, Fe	trace

The mineral *hydrozincite* is also found in the openings on this property. The following analysis is of a white coating of hydrozincite found lining cavities. In general form it closely resembled the smithsonite but it had a chalky, white appearance.

Analysis of hydrozincite from the Morning Star mines (638).

Zinc oxide, ZnO	73.24 per cent.
Carbon dioxide, CO_2	15.94 per cent.
Water, H_2O	10.54 per cent.
Silica, SiO_2	0.27 per cent.
Magnesia, MgO	0.05 per cent.
Lime, CaO	1.55 per cent.
Iron and Alumina, Fe_2O_3; Al_2O_3	0.25 per cent.
Phosphoric acid, P_2O_5; Sulphuric acid, SO_3; Manganese, Mn	traces
	101.85 per cent.

Some "tallow clay," known in the Virginia and Tennessee zinc mines as "buck fat," is also found on this property. As pointed out in the chapter on minerals, this clay frequently contains a high percentage of zinc silicate or calamine.

Analysis of "tallow clay" from the Morning Star mines (646).

Silica, SiO_2	45.60 per cent.
Alumina, Al_2O_3	20.98 per cent.
Zinc oxide, ZnO	10.70 per cent.
Iron oxide, Fe_2O_3	8.87 per cent.
Lime, CaO	1.73 per cent.
Magnesia, MgO	0.50 per cent.
Soda, Na_2O	0.30 per cent.
Potash, K_2O	2.23 per cent.
Water, H_2O	11.53 per cent.
	102.44 per cent.

On that part of the Morning Star property, formerly known as the *Ben Carney,* were found many examples of aurichalcite—the carbonate of zinc and copper.

The Morning Star Company has crushers, jigs, etc., that were built in 1898 and were operated about a year and a half. From March to July, 1900, they were not running. The ore was sacked, hauled eight miles to Buffalo on White River and from there was sent by boat to Batesville or Newport, where it was put on the railway.

The McIntosh mines are on the north or left side of Rush Creek in 17 N., 15 W., section 10, southeast quarter. The property adjoins the Morning Star on the west and the White Eagle on the east. The ore body found on the face of the bluff 140 feet above Rush Creek is the same as the bedded Ordovician deposits exposed in the Morning Star and White Eagle mines. These ore beds are prospected by several open cuts, tunnels, shafts and winzes. The following dips were observed in the tunnels:

11 degrees N. 45 degrees E. (magnetic).

17 degrees N. due (magnetic).

12 degrees N. 20 degrees E. (magnetic).

13 degrees N. 40 degrees E. (magnetic).

Those of 11 degrees and 13 degrees N. 40 degrees and 45 degrees E. appear to be about the average of the dips over the mines; the others are probably local.

The tunnels started into the hill on the ore beds have, in several cases, soon missed the ore because of the sharp dip of the beds toward the northeast.

The ore is mostly zinc blende disseminated in bluish chert beds. It occurs in streaks and lenses that follow two and sometimes three well defined strata, varying considerably in richness. The following is a section near the mouth of one of the tunnels:

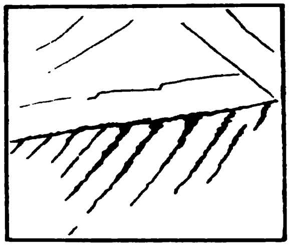


Fig. 70. Section in the McIntosh mines showing brecciation subsequent to the deposition of the bedded deposits.

In many places the cherts form breccias that have been made since the original deposition of the bedded zinc blende.

The following cut shows the structure as worked out from the openings examined January 9, 1892:

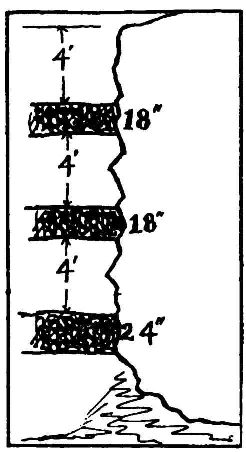


Fig. 71. Section in a tunnel of the McIntosh mine showing three zinc-bearing (shaded) beds.

The geological problems of the McIntosh property are very similar to, perhaps the same as those of adjacent properties. So far as I know the details of the geology of the hill in which the mines are located have never been worked out and mapped, and the data to be had in the several openings have never been brought together on a mine map. Such a study would greatly facilitate future development.

The beds appear to have been broken into several large blocks that now lie at various angles and are more or less displaced by faults. The ore occurs partly as bedded deposits and partly along zones of fracture that cross the beds.

In addition to the zinc blende there is more or less zinc carbonate found in the mines. In one example taken there was a vein of dolomite altered by decomposition and partly removed in solution, and the cavities thus formed were filled with zinc carbonate.

The White Eagle mines are at the mouth of Rush Creek in 17 N., 15 W., section 11, south half of the northwest quarter of the southwest quarter.

The rocks are of Ordovician age, but in the bottom lands near Buffalo River these rocks are concealed by alluvial deposits. On the western edge of the property the Ordovician rocks and the ore-bearing beds are at the surface and are the same as the beds exposed higher on the hills along the north side of Rush Creek on the McIntosh and Morning Star properties. On the east side of Buffalo River the ore-bearing beds are exposed about 20 feet above the river at the Silver Hollow mines, and 75 feet above the river at the Red Cloud property.

One of the shafts sunk on the alluvial flat on the White Eagle property is 65 feet deep, the upper 32 feet being in the alluvium. From the bottom of this is a drift which on June 20, 1899, was 55 feet long. The ore-bearing bed is a bluish chert three or four feet thick, which corresponds well both in character and thickness with the ore-bearing bed at the Silver Hollow and at the McIntosh.

The identity of the ore-bearing beds in the hillside along the north slope of the Rush Creek valley through the Morning Star, McIntosh and White Eagle properties is quite evident. The difference of elevation is due to the gentle eastward dip of the rocks which carries the ore-

bearing bed below the surface of the Buffalo River on the White Eagle property. In the White Eagle mines the rocks dip southeast at an angle of about four degrees.

The relations of the ore-bearing rocks on this property to those on the east side of Buffalo suggest a fault or a sharp synclinal fold between the White Eagle and the Red Cloud. Fig. 1 on p. 18 shows a geological section drawn along the face of the hill north of Rush Creek.

It may be, however, that instead of a single fault there are several, each with a small displacement. The theory of the fault is borne out by the statement of Mr. Frank Tegarden, who had charge of these mines at the time of my last visit (July 13, 1900). He reports a fault parallel with Buffalo River encountered in the mines. He reports also another fault in the mines running about parallel with Rush Creek, having a downthrow of 5 feet on the south. That there is a fault parallel with the creek is also borne out by the exposures west of the shafts. Here the ore beds crop out on the side of an old stripping; at one place it is 15 feet above the lower stripping at the mouth of the old stope, showing a downthrow of about 15 feet on the south side.

There are three shafts down on the White Eagle property, one of them on the Buffalo River bottoms. The rocks, as stated, are the same Calciferous beds as those of the Morning Star and McIntosh mines, but there is considerable clay here, some of which contains unusually large and beautiful crystals of calcite. The ores are zinc carbonate from the higher outcrops, and zinc blende from the shafts. Some of the rock containing zinc is brecciated chert and sandstone and the fragments are cemented with blende and quartz, the two minerals having been deposited contemporaneously, as is shown by the accompanying illustration. The drifts off the shafts are below the water level, so that the mines require pumping. Professor Purdue who vis-

Open quarry at the Red Cloud mine.

ited this property in June, 1899, notes that the ore-bearing bed is 3 feet thick, that it dips with the other rocks, and

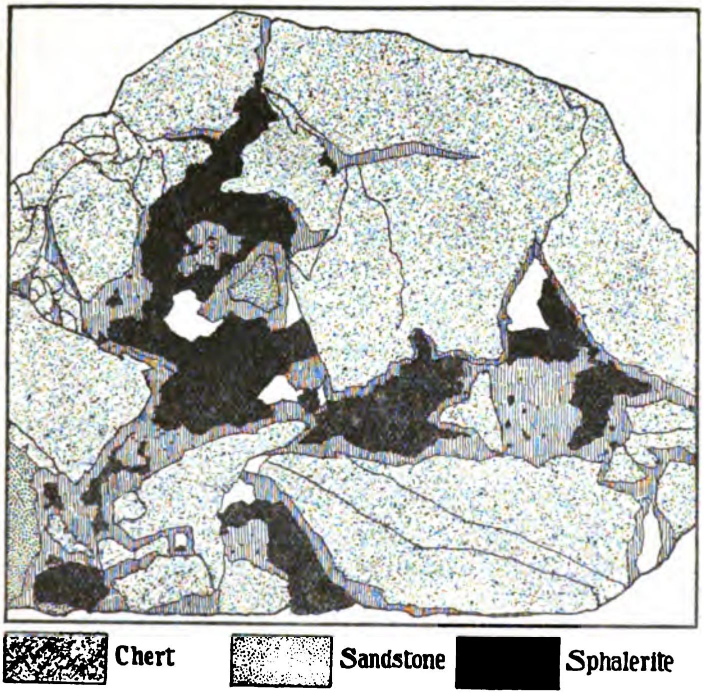


Fig. 72. Brecciated chert and sandstone cemented with quartz and zinc blende. Natural size; White Eagle mines.

that the ore occurs "largely in cross veins of varying thickness, usually not more than 3 or 4 inches."

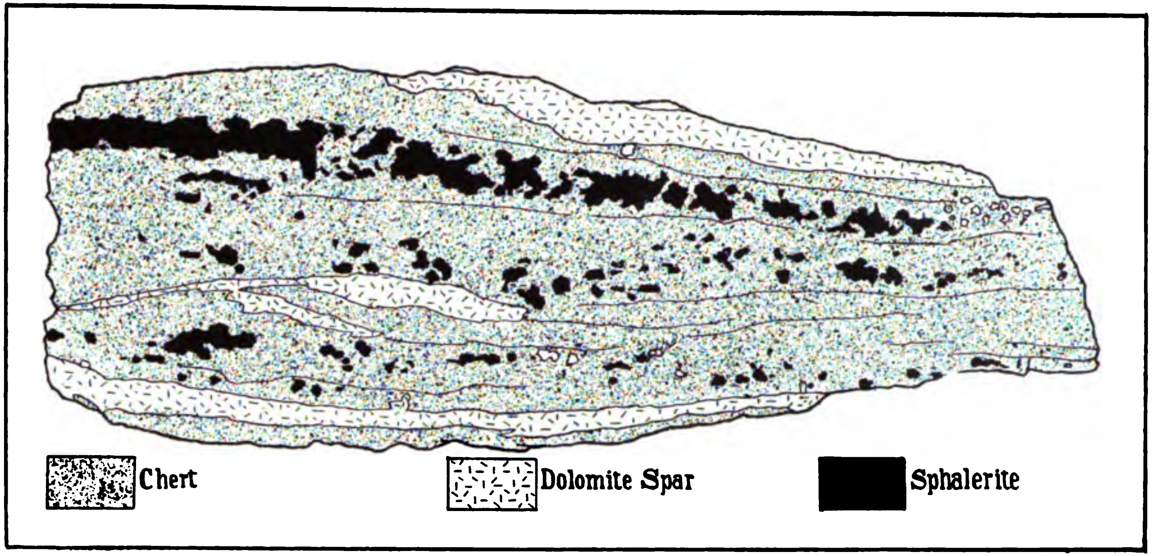
It is reported that over 500 tons of ore have been shipped from this mine.

The Red Cloud mine is on the right (east) side of Buffalo River opposite the mouth of Rush Creek, in 17 N., 15 W., section 14, northwest quarter of the northwest quarter.

The chief opening (see plate XXXIII) is on the face of the bluff overlooking Buffalo River and 70 feet above it (Barometer). This opening is (July 13, 1900) a quarry about 100 feet long by 30 to 40 feet wide and from 25 to 35 feet high. The stripping, however, is only from 3 to 8 feet

deep. The rocks are all of Calciferous age and are approximately horizontal, but they are more or less broken so that the bedding cannot be traced even across the face of the quarry. These rocks are quartzites, cherts and siliceous dolomite and quartzite breccias cemented with pure dolomite and zinc blende. The ores are mostly zinc blende found both disseminated through a bluish flint bed and filling crevices in the fractured rocks and breccias. The richer portions of the ore-bearing rock are irregular in form, size and direction, and cut across the face of the quarry at various angles. The rich flint bed cannot be clearly traced in the big quarry, but in a smaller open cut just south of the big quarry the zinc-bearing flint bed is 3 feet thick and in places very rich. Some iron pyrites occurs associated with the zinc ores about the south end of the quarry. There are also some reddish and brown zinc carbonates. Professor Purdue estimates that about one-fourth of the rock exposed on the quarry face will yield 15 per cent. of clean ore.

This property like the others in the vicinity ought to have its geology worked out in detail and put down upon a carefully constructed map. Until this is done the prospecting will be done more or less in the dark. It is not known whether the zinc-bearing flint bed exposed in the open cut south of the big Red Cloud quarry is the same as that opened upon at the Silver Hollow mine, or whether this bed is repeated in the big quarry by faulting, or whether there are here several ore-bearing beds. If the richest deposits are to be looked for in the synclinal troughs, nothing is plainer than that those troughs ought to be located by a geological examination. If on the other hand the richest ores are on the fault lines the faults should be located as closely as possible before development is seriously attempted.



Bedded disseminated zinc blende from the Red Cloud mine; natural size.

The accompanying plate (XXXIV) is made from a specimen taken in the Red Cloud quarry to illustrate the bedded or disseminated ore.

The Yellow Jacket is the name given some openings on deeded land south of the Red Cloud.* They are in Ordovician rocks on the face of the bluff toward Buffalo River and 75 feet above it at ordinary stages. One of the openings is a cut 30 feet long and 10 feet high in the back. The rocks in this cut are quartzite on the floor with siliceous dolomite above and brecciated quartzite and chert cemented with dolomite spar at the top. Both zinc blende and zinc carbonate were found here in small quantities.

Another open cut has thin bedded flint interlaminated with dolomite at the bottom, above it more massive quartzite with disseminated zinc blende, and above this granular limestone containing zinc blende in cavities (Jan. 9, 1892).

The Yellow Rose is in 17 N., 15 W., section 15, the northwest quarter, about 400 feet west of Buffalo River and at an elevation of 35 feet above the Buffalo ford near the mouth of Rush Creek.

There are four openings (Jan. 9, 1892), one an open cut 18 feet high on the face, another a cut 12 feet high on the face and a drift at the end of it 60 feet long.

The westernmost opening is a cut 40 feet long exposing the ore-bearing rock along its face.

The rocks exposed in these openings are all of Ordovician age and consist of horizontal beds of quartzites above and dolomites beneath. In the open cuts is considerable clay derived from the decomposition of some of the rock beds. in some places crystals of dolomite have been dissolved from the rocks and the cavities filled with clay.

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* I am told that there is now (Oct., 1900) a claim known as the "Yellow Jacket," in 17 N., 15 W., section 9, southeast quarter. The property described above is on the southeast side of Buffalo River, in section 14 or 15, 17 N., 15 W.

The ores are zinc carbonate, much of it in thin plates of a reddish-brown color, and some zinc blende. Some 30 tons of zinc carbonate were reported to have been shipped from the Yellow Rose (1892).

The Leader Tunnel is on the west side of gulch opening into the valley of Clabber Creek on the north side of and about 500 feet from the stream (17 N., 15 W., section 11). The general geology in the vicinity of the tunnel is the same as that of the Rush Creek district—Ordovician sediments in the lower portions of the valley and the hills capped with St. Joe marble and the Boone chert. The tunnel is in the Calciferous beds. It runs a little north of west, is 7 or 8 feet high, 7 to 10 feet wide, and when the place was visited in January, 1892, it was 177 feet long, including the side cuts.

A shaft put down on the slope of the hill above the tunnel and 69 feet from its mouth opens into the tunnel with a depth of 25 feet. One hundred and fifty feet from the mouth of the tunnel there is a cross-cut on the left in which some zinc blende was found. This tunnel is in brecciated quartzite with a sandstone roof and 2 feet of dolomite in the bottom. The ore is chiefly zinc blende, but there is also some fine zinc carbonate encrusting the blende here and there, and also encrusting the open cavities in the quartzite. The ore occurs mostly in a streak or bed at the top of the drift. In the end of the tunnel this ore is in brecciated dolomite.

Some fine specimens of hydrozincite have also been found in these openings. A partial analysis of an average sample showed it to contain the equivalent of 58.40 per cent. of metallic zinc.

The water entering the tunnel wets the roof and walls as well as the floor and is depositing over them a coating of lime carbonate.

There is a second tunnel a short distance up the gulch from the first mentioned. It is 40 feet long, 8 feet high and 20 feet wide. The rock is dolomite, quartzite and breccia, and the ore zinc blende and zinc carbonate. But little ore was to be seen when the opening was visited in January, 1892. There are several other shafts and open cuts along the slope of the hill on this property, but they show nothing of especial interest in connection with the geology of the zinc.

The ore taken from these openings was hand-sorted, hauled to Buffalo City and shipped by boat down White River.

The Philadelphia claim is on Clabber Creek in 17 N., 15 W., section 11, the west half of the northeast quarter. The geology is that of the horizontal Ordovician sediments: quartzites, cherts, dolomites and breccias. The openings consist of an open cut and a tunnel 44 feet long and 20 feet wide at the mouth. The rocks cut are somewhat brecciated quartzite on the north side and dolomite on the south side with a flat limestone roof.

The ores are zinc blende and good carbonate ore. A partial analysis of some of the carbonate showed it to contain the equivalent of 51.06 per cent. of metallic zinc—a very pure smithsonite.

The Last Chance is on Clabber Creek in 17 N., 15 W., section 11, the west half of the northeast quarter. The geology is that of the horizontal Ordovician sediments. The openings are at the same level as those of the Philadelphia, and consist of one shaft 25 feet deep and two open cuts, one of them 30 feet, the other 25 feet long. In the longer one of the cuts there is much carbonate in the rocks.

The Silver Hollow mine is on the right bank of Buffalo River in 17 N., 15 W., section 13, the north half of the northwest quarter. The rocks in which the zinc occurs form a steep slope, almost a bluff, of nearly horizontal

beds that rise from the river's edge to a height of more than 400 feet above low water. These beds are capped by the red St. Joe marble of Lower Carboniferous age, but below this marble cap all the beds are Ordovician dolomites, quartzitic sandstones and cherts.

Although the beds are approximately horizontal they are not quite so. Down-stream from the mines they have a gentle up-stream dip, while in the tunnels the dip is south into the hill, sometimes as much as 4 degrees.

Two tunnels have been driven on the ore-bearing bed which is here about 20 feet above the ordinary stage of water in Buffalo River. These tunnels are at the same level and nearly at right angles tot he face of the cliff. One of them is 65 feet long, and the other 40 feet long.

The ore bed on this property may be considered as the type of many of the zinc deposits of this part of the zinc region of north Arkansas. The bed is Ordovician chert or flint of a leaden gray, or bluish color, having the zinc blende disseminated through the mass of the rock, but with richer streaks, bands and lenticular masses following the bedding planes, and also here and there cutting across the bedding and filling cavities. This bed is from 3 to 5 feet thick, and at this place has dolomite both above and beneath it. The outcrop can be traced along the face of the bluff both up-stream and down-stream. Zinc carbonate is found along this outcrop, but in some places much more abundant than in others.

There seems to be a fault in the longer tunnel with a displacement of 2 feet.

Professor Purdue estimates that the ore-bearing bed will mill about 15 per cent. of clean ore in the better parts of the bed.

Fifty feet above and 40 feet southeast of the tunnels is another opening in the face of the bluff. It consists of an open cut of 20 feet, a tunnel of 15 feet, another tunnel of 7

Face of an open cut at the Silver Hollow mines, showing nearly vertical joints filled with limonite.

feet, and a winze 10 feet deep. The rocks here are also Ordovician. On the east side of the drift they dip 3 deg. S. 24 degrees W., and 5 degrees S. 25 degrees W. In the middle of the face of the opening the dip is somewhat steeper, but on the face of the bluff it is not quite so high.

The most striking features of these upper openings are the character of the ores and the nature and form of the ore-bearing rocks. Above the cuts are still exposed rough spongy lumps of limonite iron ore, such as are said to have cropped out when the cuts were started. As these cuts were driven into the face of the hill zinc was first found at a depth of 10 feet in the form of a brown zinc carbonate, and at 15 feet crystalline carbonate and zinc blende were found. On the face and east side of the tunnel now exposed (July, 1900) the zinc blende has much iron pyrites mixed with it.

In the shallower eastern tunnel the beds have all been jointed and the joints are filled with iron in the form of limonite. Plate XXXV shows these joints. The limonite has been altered from iron pyrites that formerly filled these cracks.

The winze in the western tunnel shows the iron in the form of limonite. The faces of the tunnel about the head of the winze are of shattered rocks of various kinds—limestones, sandstones, and quartzites, all cemented by zinc blende and dolomite, and more or less stained with iron—a remarkable ore deposit.

This opening appears to be on a fault or fracture of some kind, the nature and extent of which cannot be made out from present development and exposures. On the east side of the tunnel the rock wall is fairly well shown, but on the west side the end of the ore-bearing or crushed rock is not found, though the opening is 14 feet wide.

The geology of the ore body exposed in the upper openings ought to be carefully worked out. This could be

done by studying the fault and tracing and mapping its course.

It is reported that about 100 tons of zinc ore have been shipped from the Silver Hollow mines. The ore on the dumps will yield, according to Professor Purdue's estimate, from 15 to 20 per cent. of clean ore.

The Georgetown mine is on the left (west) side of Buffalo River in 17 N., 15 W., section 1, and on the right side of Cedar Creek Hollow. Work has been done in an open cut 68 feet long and 12 feet high at its inner end, and a shaft 57 feet deep below the bottom of the cut. The outer or southern end of the cut is in horizontal beds of

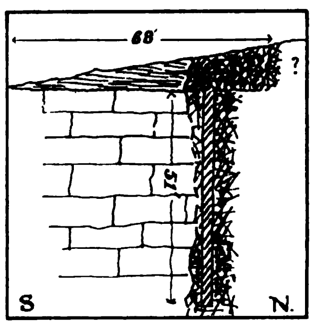
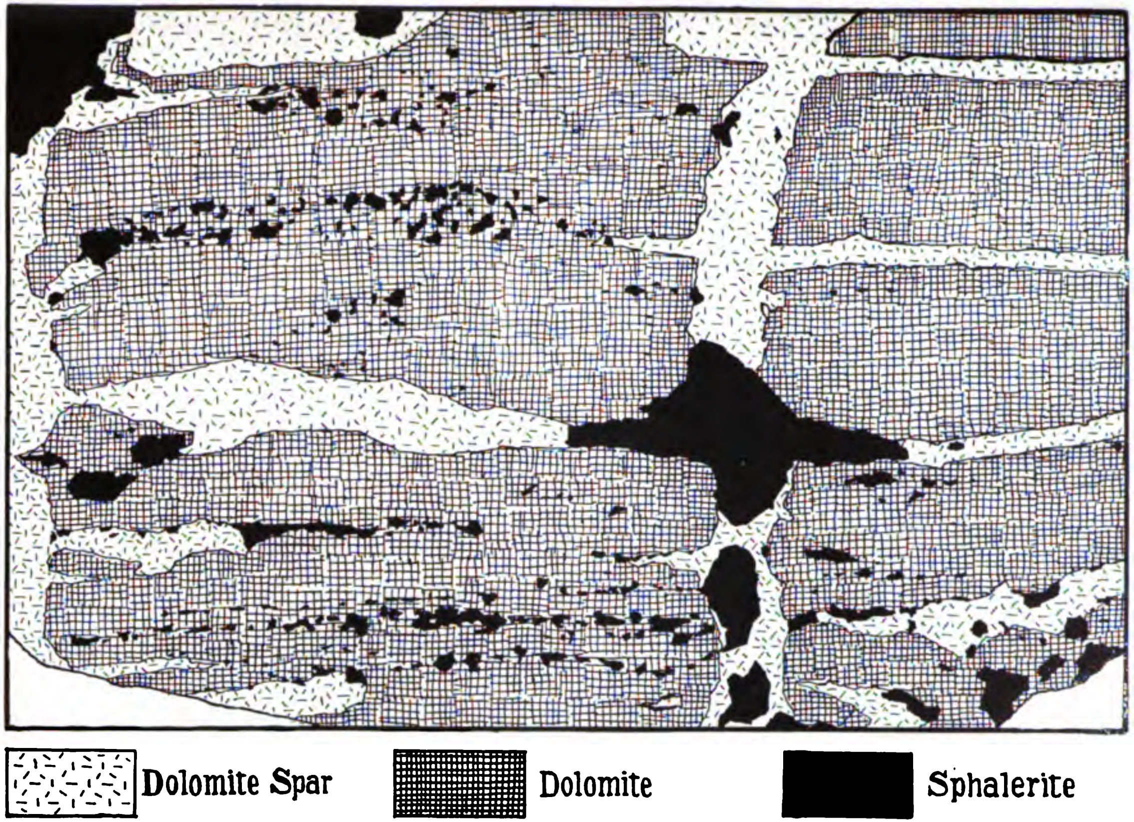


Fig. 73. Section at the Georgetown cut and shaft.

Ordovician sedimentary rocks, now more or less decomposed, while the northern end, for 20 feet from the face of the cut, is in a coarse breccia of chert, quartzite and siliceous dolomite. In the lower portion of the cut and shaft zinc blende fills what were once the crevices in the breccia; in the upper and more weathered portions of the breccia, zinc carbonate is scattered through the mass. Some of the fragments of the breccia contain interbedded and disseminated blende and these same fragments are cemented together by the blende deposited in crevices, showing that the brecciation took place after the deposition of the bedded deposits. This is shown in the accompanying illustra-



Dolomite with zinc blende disseminated and in veins of later age, Georgetown mine; natural size.

tion (plate XXXVI) made from a specimen collected at the Georgetown mine. The extent of the ore-bearing breccia on this property is not shown in this opening. The 57-foot shaft shows the breccia to contain zinc blende all the way down, but for a distance of 17 feet from the bottom the ore is especially good. It will be seen from the accompanying cut that the south face of the ore-bearing body is known only in the open cut, that it has not been struck in the shaft and that it is not known how much further it extends to the north. These data can be ascertained only by further prospecting.

The Lucky Dutchman is in 17 N., 14 W., section 7, northwest quarter, near the mouth of Cedar Creek on the left side of Buffalo River and about 30 feet above the level of the latter stream. The only place worked is an open cut 50 feet long that has produced considerable zinc carbonate. It was not being operated, July, 1900, and the clay sides of the cut had fallen in. The rocks are Calciferous dolomites and brecciated quartzites dipping nearly east toward Cedar Creek. The blende-bearing rock is a 3 to 4 foot bed of magnesian limestone with some brecciated quartzite mingled in it. The ore is partly disseminated, partly interbedded, and partly deposited in cracks.

The Let It Be claim is between Boat Creek and Cedar Creek on the left or north side of Buffalo Fork of White River in 17 N., 14 W., section 7. The rocks are the horizontal Ordovician dolomites, quartzites, and breccias of the Rush Creek region. The openings consist of an open cut and a shaft. The cut is 25 feet long, 8 feet deep and 7 feet wide. The rock exposed in it is dolomite breccia with a couple of streaks of quartzite through it. The ore is chiefly zinc blende, but there is also some zinc carbonate at and near the surface. The zinc blende occurs both as disseminated ore and in crevices associated with pink dolo-

mite spar. From some portions of the hard rock the zinc blende has been dissolved. The shaft is about 15 feet above the open cut, 30 feet away from it and has a depth of 20 feet. The rocks cut are all dolomites and no ore of consequence was struck in the shaft. (The *Let It Be* is now Oct., 1900, part of what is known as the Boat Creek property.)

Prospects.—Mr. George McCray, who is very familiar with the mining region in the big bed of Buffalo between Buffalo City and Rush Creek informs me that in 17 N., 14 W., sections 8, 9, 16 and 17, the zinc-bearing flint is just below the saccharoidal sandstone. The ore bed, he says, varies in thickness from 2 feet to 15 feet; sometimes it is unbroken and again it is brecciated. Occasionally the zinc-bearing bed is faulted, but the throw as far as known does not exceed 4 feet. The zinc blende ore is disseminated through and interbedded in this flint bed.

The Republican claim is within the drainage basin of Cow Creek in 17 N., 14 W., section 9, the northeast quarter of the southeast quarter. The high ridge that runs northwest-southeast across this section is capped by the Boone chert, but the rocks of the lower slopes of the hills all belong to the Calciferous part of the Ordovician. These prospects are 235 feet (aneroid) below the crest of the watershed between Cow Creek and Boat Creek. Here the rocks as shown by chemical analyses are chiefly dolomites and breccias. There are two small openings in the breccia and in both of them zinc blende is found associated with pink dolomite spar.

The Democrat claim, adjoining the Republican, is in 17 N., 14 W., section 9, the northeast of the southeast. The geology is the same as that of the Republican and the rocks are dolomite breccias cemented with pink dolomite spar and containing a little zinc blende. The accompanying

cut shows the brecciated nature of the ores of both these properties.

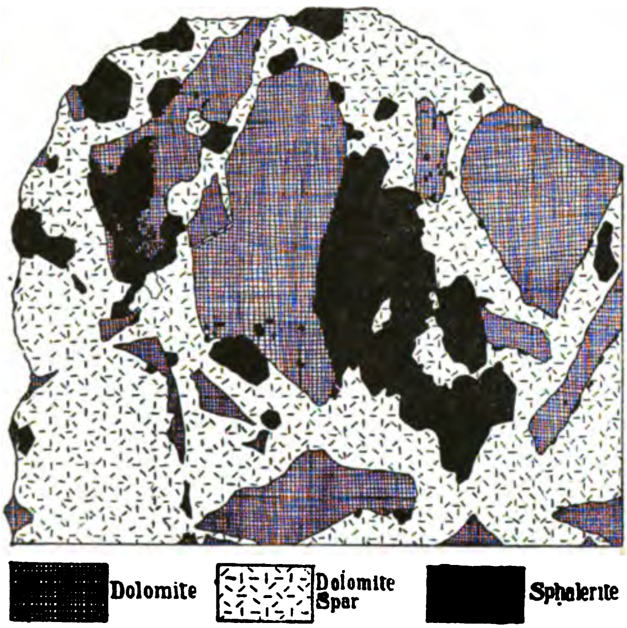


Fig. 74. Breccia from the Democrat mine, showing angular fragments of dolomite cemented with sphalerite and dolomite spar; natural size.

The Bonanza mine is in 17 N., 14 W., section 10, on Cow Creek. The property consists of the four forties around the center of the section. The rocks are well down in the Ordovician, and consist of siliceous dolomites and dolomite breccias with a little chert. The openings are about 75 feet above Cow Creek and consist of an open cut or pit 78 feet long by 30 feet across and 14 feet deep in the rock. Near the east end of this pit is a shaft 40 feet deep (i. e., below the level of the pit bottom). Some old drifts from the pit were fallen in at the time of the last visit to this property (July, 1900). On the south side of the pit unbroken rocks are in place; but on the other sides and in the floor of this opening the rocks are magnesian limestone and breccias cemented with pink dolomite spar and zinc

blende. The shaft in the cut is through this zinc-bearing breccia down to the water surface, perhaps 25 or 30 feet below the bottom of the cut.

Some open cuts have been made in the vicinity of this large one but they have been abandoned and filled up with waste. What these cuts show it is idle to speculate. Much zinc carbonate and zinc silicate were found in the open cuts and in the upper portions of the shafts. There are also here and there small pieces of chalcopyrite and crystals of aurichalcite found here. So far as can now be seen the shape, direction and extent of this zinc-bearing breccia is not known, and cannot be known without judicious prospecting. It seems clear that there is a large body of it, however. Whether or not there is a fissure through this property cannot be stated positively. I saw no evidence of a fissure.

The mining done seems to have developed no particular plan. A good deal of ore has been taken out. In December, 1891, two years after the place was discovered, 51 tons had been shipped. Some of it was prepared with bucking hammers only, but a steam crusher and hand jigs were put up on Cow Creek near the mine and were operated for a short time. The ore was hauled a mile and a half to water and shipped down White River to Newport, where it was put on cars of the Iron Mountain Railway. The man who had charge of the mine at one time states that the rock from this mine cleaned up 26½ per cent. of clean zinc blende. This statement probably refers to rock that was somewhat sorted in loading, for another statement given me on good authority was that the entire rock mass yielded 15 per cent. of clean zinc blende.

The Dry Bone mine is in 17 N., 14 W., section 3, southeast quarter, the southwest of the southeast and the southeast of the southwest, on a ridge a quarter of a mile south of the Bonanza mines. The rocks and ore are at about the

same elevation and are of the same character as those of the Bonanza, namely, dolomite breccia of Calciferous age cemented with pink dolomite spar and zinc blende. When this place was visited in January, 1892, there was a shaft 20 feet deep and some stripping. These openings showed the rocks to have been altered to clays here and there especially near the surface where there were in places only boulders of decomposition scattered through the soil or clay. In the upper portions of the openings the zinc blende crystals are coated with reddish brown zinc carbonate. The excavation is now reported to be an open cut 30 feet by 25 feet, and 15 feet deep. This property deserves more systematic prospecting. It is high above drainage so that there need be no difficulty with mine water, but it is still 250 feet below the watershed between Cow Creek and Moreland Hollow.

The Prince Frederick mine is in 17 N., 14 W., the east half of the northeast quarter of section 3, and the northwest of the northwest quarter of section 2.

The openings on this property are high on the north slopé of one of the hills that rise around the valley of Cow Creek—375 feet above White River at Buffalo. The rocks are Ordovician approximately horizontal in the region around, but at the mines dipping gently northward into the hill. They are chiefly limestones, siliceous dolomites and breccias, but in the breccias are some fragments of quartzite. The ores are smithsonite (zinc carbonate) and sphlareite (zinc sulphide) the latter predominating. The breccias are cemented with pure dolomite, zinc blende and secondary chert. I here saw no zinc ore disseminated through the rock masses; it is only in the breccia. The accompanying cut shows the relation of the ore bodies to the dolomite and "tiff." The rock is soft and could be easily crushed. (See Fig. 75.)

An important question which could not be settled when this property was last visited (July 14, 1900) is whether the ore-bearing breccia on this property is a bed

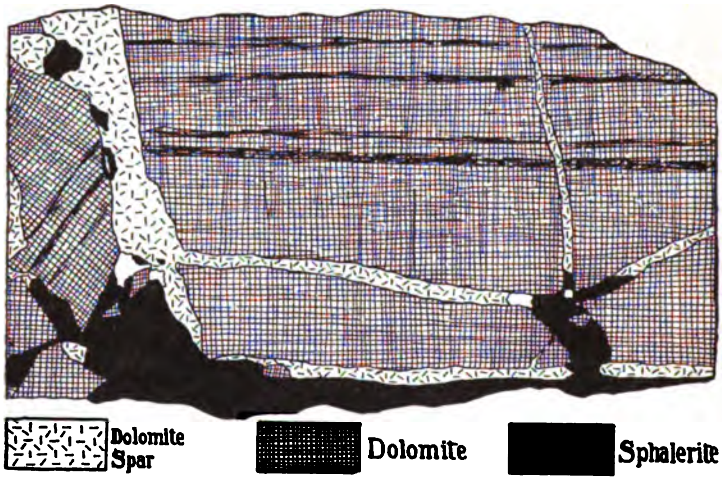


Fig. 75. Dolomite breccia, cemented with zinc blende and dolomite spar. Natural size; Prince Frederick mine.

running through the hill like the limestones and dolomites, or a fractured zone cutting these beds at a high angle. The brecciated zone appears to follow the contour of the hill, but whether this is appearance alone I am at present unable to state positively. In some of the freshly exposed cuts the beds beneath the breccia were apparently undis-

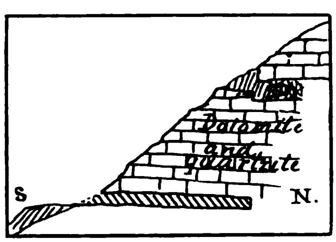


Fig. 76. Section at the Prince Frederick mine.

turbed and the beds above are but little affected by the brecciation. The uppermost open cut is in breccia where

there is a thickness of 6 feet of ore-bearing rock exposed. Below this, about 30 feet, a tunnel 40 feet long has been driven in the hill. I could not examine this tunnel for at the time of my last visit it was full of water, but I was told that zinc was found in breccia at its inner end. If this is true it would lend some support to the idea that this dolomite breccia is a more or less vertical mass. (See Fig. 76.)

The question regarding the distribution of the zinc-bearing breccia could be settled readily by stripping the brecciated masses and following them around the hill or up and down the slope. An average sample of the zinc blende from this mine was analyzed with the following results:

Analysis of sphalerite from the Prince Frederick.

Zinc, Zn	65.68 per cent.
Sulphur, S	33.33 per cent.
Silica, SiO_2	0.09 per cent.
Iron, Fe	0.15 per cent.
Magnesia, Mg	0.03 per cent.
Calcium, Ca	0.25 per cent.
Cadmium, Cd	trace
Manganese, Mn	trace
	99 53 per cent.

The Pauline mine is on the west side of Hathaway Hollow in the drainage of Laffoon Creek in 18 N., 14 W., section 33, the north half of the northeast quarter. The rocks are all horizontal Ordovician sediments, quartzites, cherts, dolomites and dolomite breccias. The principal opening, when the mine was visited in 1892, consisted of a shaft 12 feet deep at the face of a ledge 8 feet high exposed in an open cut. The ledge exposes a coarsely brecciated dolomite in which some of the angular fragments are but little out of their original positions. The zinc blende found at this place occurs in the cementing veinlets in the breccia.

In section 34, the northwest of the northeast there is an open cut in which both lead and zinc are found in Calciferous rocks.

NOTES ON THE WARNER'S CREEK DISTRICT.

The Mammoth claim is in 18 N., 14 W., section 18, the northwest quarter, about 150 feet above the V-shaped valley immediately to the northeast of it. There is a shaft 26 feet deep, all the way, save 3 feet in the bottom, in brecciated Silurian limestone containing also some fragments of flint and quartzite.

Some zinc carbonate was found near the surface, but deeper down only blende was found. This is partly disseminated in the quartzite and flint fragments, but most of it is with dolomite in the cracks of the breccia.

There is not much ore in sight at this opening. There is no rock in place exposed in the immediate vicinity. There is a prospect on *the Cox farm* in 18 N., 15 W., section 13, southeast of the northeast. The opening is a cut 20 feet long and 7 feet high near the bottom of the gulch. The rocks exposed are brecciated limestone and some quartzite in which is found a little zinc carbonate and some zinc blende disseminated through the quartzite and filling cavities in the breccia. One piece of blende was found in quartz at this cut.

The Cane Spring mines are on the right side of a hollow on the head-waters of Warner's Creek, in 18 N., 14 W., section 24, west half of the northwest quarter, and section 13, the south half of the southwest quarter. The openings are all in Ordovician, or Silurian rocks, but the Lower Carboniferous rocks (the Boone chert series) cap the hill above the mines. The principal opening is an open cut 80 feet long, 10 and 12 feet wide and 30 or 40 feet deep at the back. The upper or back end of this cut had caved in when the mines were visited in July, 1900. The rocks are dolomites or magnesian limestones, sandstones and cherts, which dip about southwest at an angle of about 5 degrees.

The inner end of the big cut is mainly in clays from which 55 tons of carbonate and silicate of zinc have been

taken. These ores follow the beds. A great deal of zinc oxide in the form of "tallow clay" has been found in this cut, and some fine lumps of "Mexican onyx" have also been taken from the opening. Some of this "Mexican onyx" was supposed to be strontianite, but a chemical examination showed it to be very pure carbonate of lime. There is some zinc blende here and there through the other ores, but comparatively little. Some blende is also found in a coarsely brecciated limestone. Along the face of the hill southwest of the big cut are ledges of brecciated limestone and sandstone and some beds of chert; in places the chert contains disseminated zinc blende. The breccias and cherts in which the ore occurs have not been well prospected, and it cannot be said whether or not they carry much ore. These beds deserve more attention than they have received on this property. There are chert breccias that are nearly white; these should also be prospected.

The Lyon Hill mines are on the right side of Warner's Creek in 18 N., 14 W., sections 28 and 29. The ore is found here in Ordovician cherts, quartzites, limestones and breccias, all at an elevation of something like 200 feet above the valley. The rocks are approximately horizontal, but at the mines they are slightly disturbed, forming a small local synclinal trough along which most of the ore

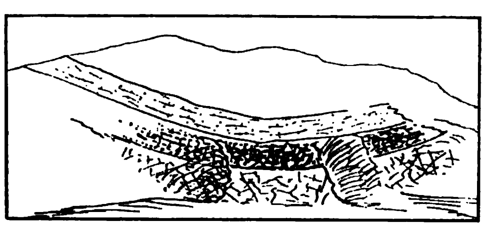


Fig. 77. Zinc blende in a synclinal fold at the Lyon Hill mines.

has been found. West of the main openings the rocks are more or less broken and the structure is not clear.

The accompanying diagrams will give an idea of the geology and the occurrence of the ore at the mouth of the tunnel. The dip of the beds at the mouth of the tunnel is 9 degrees S. 65 degrees W.

The ore in the flint is bedded and disseminated, but this bed seems to be only locally rich, so that as far as developed the deposits here are pockety.

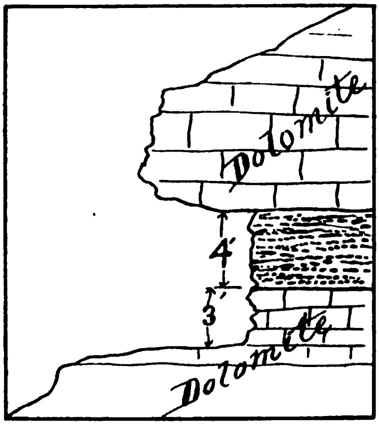


Fig. 78. Section at the face of an open cut at the Lyon Hill mines showing bedded disseminated ore in chert.

Occasional pieces of ore on the waste heaps have oxidized upon exposure, showing that there is some iron py-

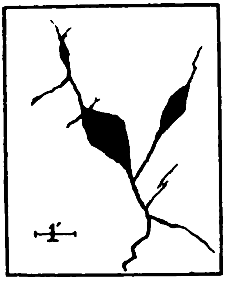


Fig. 79. Zinc blende in fractures at the Lyon Hill mines.

rites mixed with the zinc blende. This pyrites, however, does not occur with all the blende, but doubtless comes

from a local pocket. Some of the blende is found in cracks in quartzites. The above is a figure (79) of one of these fractures filled with zinc blende.

A tram or slope has been built from the mines on the hills here to the crushers and jigs in the valley below and work appears to have been actively carried on at this place for some time—just how long I could not learn. The mines and mills are said to have been stopped after shipping about 20 tons of clean ore. The mills are only about three miles from Buffalo landing on White River, and the road, as roads go in this part of the State, is very good, and there are no high or steep hills to climb.

General remarks upon the Warner's Creek region.—In the Warner's Creek region the rocks are Ordovician in the valleys, and only a few of the highest hills are capped by beds belonging to the Boone chert series. The Ordovician rocks are horizontal in the main over the entire region, but they are here and there locally folded somewhat and in all probability faulted, too, though no faults have been observed in the region by the writer. These Ordovician beds consist of limestones and dolomites, sandstones, quartzites and cherts, and breccias made up of fragments of all these kinds of rocks. The zinc ores that have been found in this region are both disseminated in the flints and free ores cementing the breccias. The only attempts that have been made to work the deposits on Warner's Creek were at the Cane Spring mines, where the carbonates were mined for some time, and at Lyon Hill, where crushers and jigs and other machinery were put up and operated for a while. The ores from the Cane Spring mines had to be hauled about 6 miles and those from Lyon Hill 3 miles to Buffalo City, where they were loaded in barges and sent out by way of Batesville.

There has been comparatively little prospecting done in this region. The geology has not been worked out in

detail and it is not clear from the developments that have been made whether large bodies of disseminated zinc blende occur in the flints, and whether other large bodies are to be expected in the breccias. To test these rocks is a much easier thing than many of the prospectors appear to think. It is the custom to run long open cuts and drifts or to sink deep shafts for the purpose of testing the properties. In most cases such large openings are expensive and unnecessary. When the zinc is in a flint bed the prospecting should follow round the hill on the outcrop, and once the weathered portion of the rock is blasted off there is no reason for running in a long drift in order to find out whether the bed is ore-bearing. It is much cheaper to carry the prospecting along the face of the hill. If it is found that these beds are richer in the synclinal troughs then these lower places especially should be sought out and prospected. If the ore is in the breccia the prospector should first find out whether this breccia is a horizontal bed or a fractured zone cutting the horizontal beds at a high angle or only an irregular or lenticular mass. If it is a bed following a contour of the hills the prospecting should follow this contour just as if it were a horizontal bed of limestone or sandstone.

It is often assumed that the broken condition of the breccias is evidence of the faulting of the rocks. This is sometimes the case, but not always. In many instances the breccias have been found to lie between two undisturbed beds of sediments. But whatever the form of the ore-bearing bed may be it may be assumed at the outset that the directions of the present streams and hollows have no apparent connection with the ore deposits.

NOTES ON THE BAXTER COUNTY OPENINGS NORTH OF WHITE RIVER.

General remarks upon the geology of Baxter County.—The rocks of Baxter County north of White River are of Ordovician or Lower Silurian age. The only exception I know to this rule is in the case of the high hill on the north-west side of White River at Ship's Ferry. That hill is capped by the red St. Joe marble and above the marble is the Boone chert. These beds in the hilltop belong to the Lower Carboniferous series. It is quite possible, however, that there are a few other high hills capped by these beds, especially in the country along White River. Everywhere these Ordovician beds are nearly horizontal. In these broad sheets of sediments the drainage of the country has cut down steep-sided valleys and the horzizontal bedding of the rocks may be seen in the bare ledges of their sides and in the steep-faced bluffs of any of the larger streams. The hills that rise above the general level of the country are only the remnants of beds that have been removed by the long, slow processes of erosion.

Plate II, taken from the hills east of Denton's Ferry, shows a type of the valleys cut by the White River and of the mountains in the distance. The hills north of Mountain Home known as Wallace Knob, Sorrel's Knob and Pink Smith Mountain are the remnants of some of the upper beds of the Ordovician rocks left by erosion.

Plate V, taken from south of Mountain Home, shows some of these elevations and gives a good idea of the Ordovician plateau of the northern part of the State.

Occasionally very gentle folds can be made out in the otherwise horizontal rocks of this region. In the main, too, these Ordovician beds are continuous, but to this rule also there are some exceptions and the continuity of the beds is broken by faults. How great these faults are is not now known.

The geology of the country has never been worked out in detail, and the sequence of the rocks is at present unknown. The apparent similarity of the beds in the Ordovician adds to the difficulty of detecting faults without considerable study of the structure. The case of the Lost Mine shows that there are faults and that mineral-bearing veins may be looked for in Baxter County. Most of the zinc prospects suggest that zinc in Baxter County is to be expected in the form of bedded deposits. The local prospectors have found this out for themselves and are very properly sticking to these beds in their prospecting. It is probable, however, that the richest of the deposits will be found in the sags or lower synclinal folds of the beds, and much time and money may be saved if prospectors will seek out these folds and prospect them by preference.

But little geological work has been done in Baxter County north of White River. A few of the zinc and lead prospects have been visited for the purpose of getting an idea of the geological distribution of the ores. From what could be learned it seems probable that those mentioned below may be regarded as types of the prospects of the county.

The Michigan prospect is on the hilltops near and on the north side of White River (left bank) in 17 N., 14 W., section 1, west half of the northeast quarter, and the northeast quarter of the northwest fractional quarter. The rocks of the vicinity are horizontal Ordovician beds of flint, breccia and dolomite. The ores are zinc carbonate in the upper weathered portions and zinc blende in the deeper and unweathered parts. There are two open cuts, one of them having a pit 7 feet deep at its inner end.

The ore is found both in the crevices between fragments and disseminated in the 2-foot flint bed near the top of the cut. Some of the cracks in the dolomite are so small that zinc blende in them looks here and there as if it were disseminated.

The form and size of the ore body is not determined by these openings, but the prospect is a promising one.

The Partnership claim joins the Michigan on the west. It is in 17 N., 14 W., section 1, northwest quarter of the northwest fractional quarter. The rocks exposed in two openings are Ordovician brecciated dolomites with zinc blende in the cracks. The locality is a promising one and should be further prospected.

The Gilliland shaft is on deeded land on the plateau east of White River in 19 N., 14 W., section 25, south half of the southwest quarter.

The rocks are horizontal Ordovician limestones and dolomites containing zinc blende in dolomitic breccia. The rock is soft, but the breccia contains a little chert and bits of sandstone.

The shaft is 15 feet deep; it passes through a 10-foot bed of brecciated dolomite containing zinc blende, and below that passes into a barren dolomite.

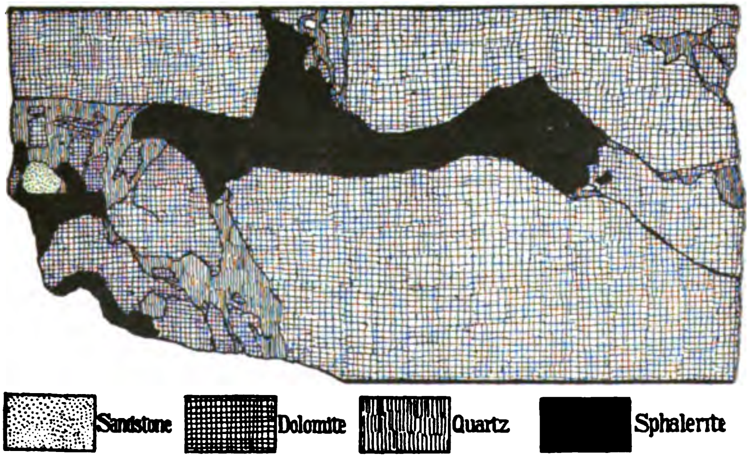


Fig. 80. Dolomite breccia cemented with quartz and zince blende. Natural size; Gilliland shaft, Baxter county.

The accompanying cut shows the dolomite of this mine cemented with zinc blende and a little quartz.

The Commercial shaft is also on deeded land on the same plateau as the Gilliland and is in 19 N., 14 W., section 25, the northwest quarter of the southeast quarter. The rocks are likewise horizontal brecciated dolomitic limestones and some chert and quartzite of Ordovician age. The zinc blende occurs in the dolomite breccia, and there is a little zinc carbonate. The shaft is about 40 feet deep. The thickness of the ore-bearing breccia could not be seen exactly but it appears to be from 7 to 10 feet. The ore-bed is probably the same as that cut in the Gilliland shaft. The character of the ore at this shaft is excellent, but no considerable ore body has yet been found (July 16, 1900).

The Jones prospect is in 19 N., 14 W., section 4, southwest quarter of the northwest quarter. The rocks are horizontal Ordovician(?) siliceous dolomites, somewhat brecciated. A few shallow pits opened have uncovered a little blende and zinc carbonate in the cracks.

The Big John claim is in 19 N., 14 W., section 5, the north half of the northwest quarter, a mile and a half northeast of White River. The openings are on the right side of a branch of Bruce Creek about 100 feet up the side of the hill, and are all open cuts or strippings along the

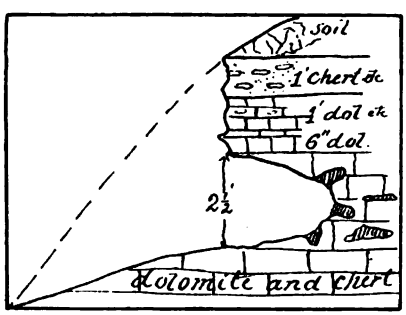


Fig. 81. Geological section at the Big John openings.

horizontal Ordovician beds. But little ore has been found and this is chiefly in the form of brown zinc carbonate.

Some of the zinc carbonate found at this place is in the form of a red "sand," almost a powder. A chemical examination was made of this material, and it was found to be an impure smithsonite containing silica, a little iron and traces of copper. A little zinc blende has also been found. The ores occur in pockets in a horizontal siliceous dolomite bed from 2½ feet to 4 feet in thickness.

The prospecting here follows the bed containing the zinc around the hills. This method is the one best adapted to discover, at the least possible expense, a paying deposit if it exists.

The Bruce Creek Hawkeye, or Hawkeye No. 2, is in 20 N., 14 W., section 31, the southeast quarter of the northwest quarter. It is on a ridge overlooking Bruce Creek and about a mile from White River. The openings are open cuts driven into the hill near the summit, the largest of which is 50 feet long, 7 feet wide and 12 feet high in the back.

The rocks are horizontal Ordovician chert, siliceous dolomite and residuary clay. The ores are zinc carbonate and blende found both in the chert and in the limestone, but only in cracks—not disseminated through the beds. The ore-bearing bed crops out all around the hill, always beneath the chert bed.

The Gold Standard claim is in 20 N., 14 W., section 30, the southeast quarter of the southeast quarter. The rocks cut in prospecting are all horizontal Ordovician beds. At one place a face 40 feet long and 3 feet high has been opened along the outcrop of the zinc-bearing siliceous dolomite that shows many irregular cavities.

Both above and below the zinc-bearing bed are dolomites. There are chert nodules in both the underlying and overlying dolomite beds.

Only a little zinc ore has been found here, but the system of prospecting is the one best adapted to discover the zinc if it exists in paying quantities.

The Lost mine is in 20 N., 13 W., section 2, southwest quarter, and section 3, the southeast quarter. The openings are along and near the bottom of a hollow that drains into Pigeon Creek, a tributary of the North Fork of White River. One open cut on the east side of this hollow is 15 feet high in the back and 15 feet long.

The rocks exposed are all of Ordovician age, are horizontal and are chiefly siliceous dolomites containing a few small flint nodules. These are cut by a vein of broken material from 14 inches to 4 feet in width. The material of the vein is of the same kind as the wall rock but mostly in pieces smaller than one's fist. This vein contains some galena scattered through it, and branching off from it in little stringers that pass into the wall rock.

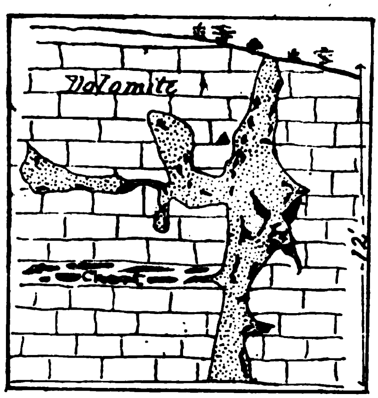


Fig. 62. Section of the fault and lead vein at the Lost mine, Baxter county.

The rocks on opposite sides of this vein show that the vein is in a fault. Just how much the displacement has been cannot be stated without more study than it was possible to give the matter when the place was visited (July 18, 1900). It seems probable that the fault is only a small one for the walls on opposite sides of the vein are so nearly alike that it was only by trying to trace the chert nodules across the vein that it could be seen that there was any displacement at all. The break in these beds is nearly ver-

tical and the extent and direction of the vein and the lead ore could readily be determined by cross-cutting on the surface of the ground along the strike of the vein.

The Hawkeye claim is in 21 N., 13 W., section 36, southeast quarter of the southeast quarter. The openings are on the side of a hill that slopes westward toward Buck Branch about three-quarters of a mile from the North Fork of White River.

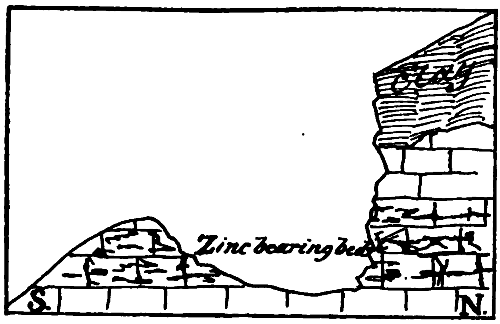


Fig. 88. Section at the Hawkeye mines, Baxter county,

The rocks cut are nearly horizontal Ordovician beds, mostly siliceous dolomites or highly siliceous magnesian limestones, with some quartzites and chert. The open cuts follow the outcrops along the hillside. At one point, however, a cut starts into the hill and now has (July 18, 1900) a face 15 feet high at the back.

The ores are both zinc carbonate and zinc blende. The blende occurs in cavities and cracks in breccia following a definite horizon or bed about 5 feet thick while the carbonate ore coats the rocks here and there along the same bed. The accompanying cut is from a drawing made of a specimen of dolomite from this mine having its cracks filled with zinc blende. At this place I saw crystals of zinc blende with quartz crystals imbedded in the zinc. A little galena has also been found at this place in brecciated dolomite. A chemical examination of the country rock of

this property shows it to be a highly siliceous magnesian limestone, and that it contains zinc and a small amount of iron and alumina.

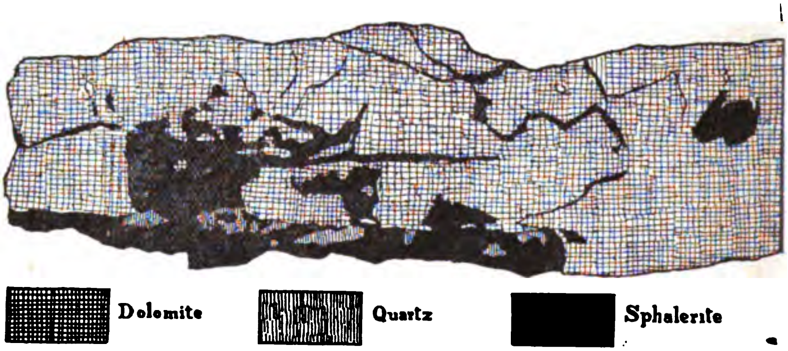


Fig. 84. Dolomite containing zinc blende and quartz in fractures. Natural size; Hawkeye mine, Baxter county.

The Halsenbeck prospect is across the hill east of the Hawkeye. I did not visit this property, but the rocks are reported to be dolomites, quartzites, cherts and breccias like those found at the Hawkeye, while the zinc blende and zinc carbonate follow a horizontal bed in the same way.

The Bean prospects are in 21 N., 12 W., section 22, northwest quarter. They are in the face of the bluff on the North Fork of White River and on the left side of that stream. The rocks are horizontal Ordovician beds consisting of siliceous dolomite, quartzite and some chert. In one pit 12 feet deep and 7 feet wide some good size carbonate was found. At other openings the ore-bearing ledge has been blasted into and some good zinc carbonate with a little zinc blende found. The bed containing the ore is 8 feet thick, but the several openings visited (July 18, 1900) had not developed ore in paying quantities. A few fossils found in the cherts immediately overlying the ore-bearing beds prove to be of Calciferous age, that is, they are at the bottom of the Ordovician or Lower Silurian beds.

THE LAWRENCE AND SHARP COUNTY ZINC DEPOSITS.

*Historical**—The zinc deposits of north Arkansas that have been longest known and upon which the most persistent efforts have been made toward development are those of Lawrence and Sharp counties. As long ago as 1857, a zinc smelter was erected at Calamine in Sharp County, by the Independence Mining Company, with Mr. Faber, general manager, and Mr. Hoppe, of St. Louis, one of the main promoters. This company is said to have shipped about 100 tons of zinc in addition to what it smelted. The operations of this company were stopped by the civil war, and their machinery was used or destroyed by the Confederate army. In 1868 the Independence Mining Company sold out to the American Zinc Company and the latter operated the smelter in 1871-2. The American Company made spelter but shipped no zinc ore. It worked the mines for about two years, but the smelter was operated for only about six months. Only carbonate ore was used, chiefly from the Hoppe, Rainey and Koch mines. In September, 1899, the company set up a crusher and jigs and began operations again. When the property was visited in July, 1900, the machinery was not being worked and it had the appearance of having been but little used.

No statistics are at hand showing the amount of ore produced by the mines or the spelter made by the smelters. From the facts that can be gathered one gets the impression that these mines have never been profitable. This impression, however, is not based upon facts and figures, and even if it were, it must not be accepted to mean that the zinc deposits of Sharp and Lawrence counties are necessarily unprofitable. The method employed in much of the prospecting in the vicinity of Calamine is one well adapted to other regions.

* For historical data I am under obligation to Capt. W. C. Sloan, of Smithville, and to John Casper.

Topographic features.—The zinc ores of this portion of the State are found in the hilly country between Black Rock and Evening Shade. Most of the area within which ores have been found lies within the drainage of Strawberry River. It is quite impossible to give the exact limits of the zinc region of this portion of the State for there has not been prospecting enough done to determine its limits. Within this area the hills are rounding, not very high—the highest are only about 150 feet above the valley—and the soil is a brick clay or yellow loam several feet in depth. This clay is partly the result of the decomposition of the underlying rocks, but probably in part the result of a comparatively recent sedimentation.

The geology.—The rocks of the region are all of Ordovician (Lower Silurian) age, but for lack of fossils to make a closer determination it is not possible to say whether they represent more than one of the subdivisions of the Ordovician. The geology of the region about Batesville has been worked out by the State Geological Survey in considerdable detail and that geology throws a great deal of light upon the zinc region of Lawrence and Sharp counties. It can be pretty confidently said that these zinc-bearing rocks belong to the Calciferous horizon of the Ordovician and that they are the equivalents of the zinc-bearing Ordovician rocks of Baxter, Marion, Boone, Newton and adjoining counties.

The rocks are ordinary limestones, dolomites, magnesian limestones, sandstones, quartzites, cherts or flints and breccias. The order in which these rocks occur has not yet been worked out. Such a detailed study would require the services of an expert paleontologist, and more time and money than we have had at our command. Only such an investigation will show just where the zinc beds are to be looked for, how many there are of them, and how they can be located and identified by the prospectors.

The deepest section ever recorded in the Ordovician rocks of north Arkansas is that made in boring a deep well at the Southern mine near Cushman, Independence County. This well is 2040 feet deep. Samples of the rocks passed through were preserved and the superintendent, Mr. S. R. Kennedy, kindly furnished the drill record and allowed the State Geological Survey to examine the drillings. From these samples the following section was constructed by Dr. R. A. F. Penrose, Geological Assistant:

Record of the deep well at the Southern mine, near Cushman, Arkansas.

Kind of rock.	Feet.
Detritus	50
Izard limestone	240
Sandy limestone	10
Saccharoidal sandstone	125
Calcareous sandstone with interbedded gray limestone and sandstone	45
Massive gray and brown limestone with disseminated sand grains	38
Massive gray limestone with sand grains (82') running into chocolate-brown limestone with sand grains (15')	97
Slightly calcareous gray sandstone	9
Highly calcareous gray sandstone	82
Massive chocolate brown and gray limestones	19
Massive gray limestone	70
Massive gray limestone harder than last	115
Slightly sandy gray limestone (4') passing at its base into white sandstone (51')	55
Sandy dark gray limestone	45
Fine grained, calcareous, gray sandstone becoming coarser at the base	180
Massive gray limestone with sand grains	25
Fine grained white sandstone	25
Sandy gray limestone running into fine grained white sandstone	20
Massive, chocolate-brown limestone	75
Massive, gray limestone with fine sand grains	75
Massive, gray limestone with coarser sand grains	80
Massive, gray limestone	80
Fine grained white sandstone	20
Massive, gray limestone with grains of sand	45
Fine grained calcareous gray sandstone	55
Fine grained calcareous white sandstone	140
Shaly gray limestone with thin strata of green shale passing at its base into a shaly calcareous sandstone (2')	52
Very fine grained, calcareous gray sandstone with thin beds of black shale	208
Cream colored gray limestone	115
Total depth	2040

The Izard limestone at the top of this section has yielded only a few fossils, but the St. Clair beds that overlie the Izard limestone have yielded an abundance. The St. Clair beds are of Niagara age or the bottom strata of the upper Silurian.* The Izard limestone and all the beds below it belong therefore to the Lower Silurian or Ordovician, unless there happens to be some beds of Cambrian age at the base of the series.

It is probable that some of the limestones mentioned in the section are magnesian limestone and dolomites, but no chemical examination has been made of the drillings and it is impossible in the absence of such an examination to be positive on this point.

Passing from the Cushman district into the zinc region of Sharp and Lawrence counties it is impossible without more field work to correlate the beds of the above section with those of the zinc region.

The following section from the hills south of Sulphur Rock to Hazel Grove may help in future work in this district to connect the geology of the Batesville region with that of the zinc region northeast of there.

Fig. 85. Northeast-southwest geological section through Sulphur Rock and Hazel Grove, Independence County, showing the general geologic structures.

Dr. Penrose, who kindly made some notes upon the zinc region of Sharp and Lawrence counties for me in 1893, is of the opinion that the limestones in which the zinc is

* Dr. Henry S. Williams, of Yale University, has kindly examined the fossils collected by the Survey and determined the age of these rocks.

found immediately underlies the sandstone and chert which carry the iron ores of northeastern Arkansas.*

The general geology of the country leads me to the belief that the zinc-bearing beds of Lawrence and Sharp counties are at about the same horizon in the Ordovician as they are in Baxter, Marion, Newton and Boone counties.

NOTES ON THE MINES AND PROSPECTS OF SHARP AND LAWRENCE COUNTIES.

The Calamine mines are at and about the village of Calamine, Sharp County, in 16 N., 4 W., section 22. The surrounding country is rolling with gently sloping hills and a deep soil.

The rocks of the region are chiefly dolomites, brecciated magnesian limestones, and quartzites, all of them of Ordovician age. Owen gives the following as the order of the rocks at Calamine beginning at the top of the hill above the openings and going down the hill to the big spring.

	feet
Slope covered with chert and iron resting on limestone with chert	35
Zinc ore bed on cherty magnesian limestones	35
Calciferous sandstone	10
Magnesian limestone	16

It is not meant here that the zinc is 35 feet thick, but that the beds in which the zinc is found have this thickness.

Many prospect holes have been opened, some as shafts, some as tunnels and some as pits or open cuts. One of these openings on the west side of Mill Creek is, or was, connected with the crushing plant by a tramway. This consists of an open cut 285 feet long (195 feet in clay and 90 feet in rock and clay) with a tunnel (length not measured) at the end of it. The rock exposed in this cut and tunnel is dolomite, here and there slightly brecciated and having a little zinc blende filling cracks throughout it.

* See Geol. Survey Ark. for 1892, vol. I, pp. 20-25.

The ore-bearing bed is 8 feet in thickness and extends to the bottom of the cut. There are a few small pockets of zinc carbonate or zinc silicate. Beyond the tunnel are shafts, one of them 41 feet deep, and one now sinking (July 20, 1900) 70 feet deep. The following diagram shows the probable relation of the rocks of the tunnel to those of the shafts:

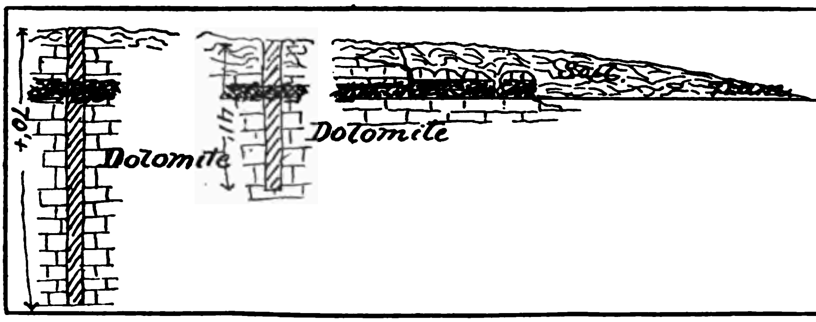


Fig 86. Sections at Calamine showing the probable relations of the ore beds cut in different shafts.

The following is the analysis of the ore-bearing bed as given by Elderhorst:*

Insoluble silicates	10.985 per cent.
Iron, alumina, and trace of magnesium	1 482 per cent.
Carbonate of lime	50.075 per cent.
Carbonate of magnesia	32.487 per cent.
Potash	0.186 per cent.
Organic matter and loss	4.885 per cent.
	100.000

This means of course that this rock is a true dolomite.

Now and then iron pyrites is found associated with the zinc blende at Calamine. So far as could be ascertained no large bodies of zinc blende have been found at this place. The smelting done here in the past was done with zinc carbonate and perhaps with some zinc silicate. The ores were not all obtained at Calamine, but were

* First report of a geological reconnoissance. By D. D. Owen, p. 174-175. Little Rock, 1858.

hauled from several other mines in the vicinity, especially from the Hoppe mine and the Rainey mine.

The Casper mine is on deeded land in 16 N., 2 W., section 18, northeast quarter, within the drainage of Big Cypress Creek and a quarter of a mile from that stream. The rocks in which the ore is found are dolomites, somewhat brecciated and of Ordovician age. These rocks for the most part have a gentle northward (3 degrees to 5 degrees) dip in the neighborhood, but just at the mine they are bent so as to make a shallow monocline.

The prospects consist (July 21, 1900) of two open cuts, one of which is 15 feet across and exposes a thickness of 12 feet of rock and soil. The bottom 6 feet of this is a zinc-bearing brecciated dolomite with much zinc blende in the cracks. The underlying bed is barren, but the zinc blende extends six or eight inches into the overlying bed.

In a second open cut and tunnel (23 feet long) about 100 feet north of the first mentioned opening a rich streak of ore was struck in a bed that appears to overlie the ore-bearing bed of the first cut. The relations of the two ore deposits are suggested by the following cut:

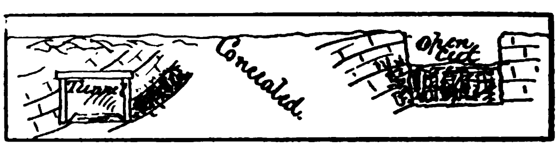


Fig. 87. Section at the Casper mines.

It is possible, however, that there is a small fault between these openings and that the ore in the two cuts are in or are part of the same ore-bearing body. This, however, can only be determined by further exploration of the space between the two openings.

The ores at this mine are mostly zinc blende in the cracks in a partly brecciated dolomite, but there is also

some zinc carbonate. There is a little iron pyrites in some of the gangue rock of the blende ores.

The Gibson mine is seven miles west of Black Rock and six miles from Imboden in 17 N., 2 W., section 9, southeast quarter. Soil and water-worn gravel cover the rocks to a depth of from 2 to 6 feet. The rocks are all of Ordovician age, and are mostly siliceous magnesian limestone. They are about horizontal where exposed in the open cuts examined. There is some zinc carbonate, but most of the ore found in zinc blende in cracks and slightly disseminated through the bluish magnesian limestone. There are several openings on this property, but at the time of my visit (July 21, 1900) they were mostly filled with water. At the bottom of one of the largest open cuts is a dark brecciated dolomite from which most of the zinc is said to have come. This ore-bearing bed is said to have been penetrated to a depth of 3 feet. The greatest thickness of the ore-baring bed reported is 12 feet. So far as can be gathered from conversation with persons acquainted with the workings the ore is at about the same level in the various openings. There is a crusher and hand jigs on the property and a carload of zinc blende is said to have been shipped from these mines.

The Hoppe mine is in 16 N., 2 W., section 19, the southeast quarter, and about 9 miles east of Calamine. It is on the northwest side of a hill about 50 feet above the valley. This is one of the old zinc mines of the State having been worked by the American Zinc Company as early as 1867 or 1868.

The rocks are of Ordovician age. The following analysis of the gangue rock at this mine shows it to be a dolomite:*

* First report of a geological reconnoissance. By D. D. Owen, p. 174. Little Rock, 1858.

Analysis of gangue rock at the Hoppe.

Insoluble silcates	6.704 per cent.
Carbonate of lime	53.998 per cent.
Carbonate of magnesia	35.059 per cent.
Carbonate of iron	2.258 per cent.
Carbonate of zinc	1.978 per cent.
Potash	0 106 per cent.
	100.098 per cent.

The ore taken from the Hoppe mine was chiefly zinc carbonate, which is found in clay that overlies the dolomite. In some cases the dolomite is brecciated and cemented with zinc carbonate. The largest pocket of ore seen is 10 feet wide and was exposed to a depth of 8 feet with ore still in the bottom. The workings are open cuts and pits, but they are now mostly filled up. There was one shaft about 30 feet deep that showed some zinc blende in the bottom. This shaft is now filled up.

The Rainey mine is in 16 N., 3 W., section 15, northwest quarter. The general geology of the region about this mine is about the same as that of the other mines in the neighborhood of Smithville. It is one of the oldest zinc mines in the State and was worked when the smelter was in operation at Calamine. The ores are chiefly zinc carbonate taken from open cuts, but there is a little zinc blende also.

The Richardson mine is about three-quarters of a mile northeast of Smithville in 17 N., 3 W., section 27. The rocks are Ordovician, and the ores are both carbonate and sulphide of zinc. This was one of the most productive mines when the smelter at Calamine was in operation. This mine was not visited by the Survey; the notes above were kindly furnished by Mr. John Casper.

The Minner Zinc Mine is in 17 N., 2 W., section 9, the southeast quarter. The zinc ore here is of a similar kind, and occurs in a similar rock to that at the Hoppe mine. Several small pits have been made on the limestone show-

ing more or less ore. One pit 10x10 feet square and 8 feet deep shows a bunch of blende and pink calcite forming an irregular pocket in the limestone about 3 feet in diameter. Ore composes probably one-eighth part of the bunch. Specks of ore also occur in the chert masses and layers which form a part of the limestone formation.

The Minner Lead mine is in 17 N., 2 W., section 10, the southeast quarter of the southwest quarter. Galena occurs here as crystals and thin seams scattered sparingly through the same limestone that carries the zinc at the Minner zinc mine. A large hole, at least 60 feet deep, has been sunk on the deposit.

The Holloway tract is in 17 N., 1 W., section 20, the east half of the southwest quarter. Several small prospecting pits on this property show crystals and small pockets of blende and carbonate of zinc in a limestone similar to that described.

Similar exposures of ore are seen on other tracts owned by Mr. Holloway in this region.

Zinc ore, mostly blende, occurs in the same associations in several other places in the vicinity of Black Rock. No large deposits were seen, but only a part of the localities were visited. Prospecting is being done in many places, but no important amount of ore is being shipped.

General conclusions on Sharp and Lawrence counties. —Owing to the lower relief of the region, the deeper decay of the rocks and the overwash of late sedimentary deposits, the geology of Lawrence and Sharp counties is not so easily worked out in its structural details as that of the counties further west. In the main, however, the geology is the same as that of the western counties.

The rocks are of Silurian age, the beds are slightly folded and the zinc is confined to a definite bed or beds. Over most of the zinc region these beds are too poor to be worked, but it is highly probable that the sul-

phide ore bed has richer portions that will be profitable to work. Just where these richer portions are cannot be positively stated with our present knowledge, but it is very probable that they will be found in the synclinal troughs. These troughs can be located sometimes exactly and somtimes only approximately by a careful geological and instrumental survey. They may be stumbled upon by indiscriminate prospecting, but this is an expensive and uncertain way to make a preliminary geological examination.

The zinc carbonate has been derived by alteration from the sulphide ores, and as the alteration of the rocks by weathering in this portion of the State has been deep, carbonate ores are to be looked for along the soil-covered portions of the outcrop of the zinc-bearing bed or beds. If the rocks of the region were all horizontal the location of this line of zinc carbonate would be simple and easy; but the rocks are somewhat folded so that the ores are at one elevation on one side of a hill or valley and at quite another on the other side a quarter of a mile or a mile away.

The greatest bodies of zinc carbonate will be found in the soil and clay where the rocks in place form synclinal troughs and at the same horizon as the zinc-bearing beds.

It has been asked whether ore might not be looked for in the low lands east of Black River. There is no doubt but that the zinc-bearing rocks do extend beneath the later deposits on that side of the river, but the deposits could be located there only by means of many deep shafts and bore holes put down in very wet ground. The expensiveness of such a method of exploration is not likely to commend it as long as the same ore beds can be found in the higher uncovered region west of Black River.

CHAPTER V.

METHODS OF PROSPECTING.

Much of the prospecting done in the zinc and lead regions of north Arkansas has been done as intelligently as it is possible to have it done. The people doing the work have studied the rocks and the ores and have followed nature—the best possible guide in such matters. In other instances the prospectors have come into this region with long and valuable experience elsewhere that would have been of the greatest value where the experience was obtained, but here it was simply misleading. The results have been unfortunate for every one concerned.

Whether or not the methods followed in prospecting are the best that could be used can be determined only when it is known how the ores occur. If one has to deal with a piece of geology like that represented in the accompanying cut it is plain at a glance that a mine can be best opened by a tunnel or adit driven into the hill along the ore bed from the outcrop. It is no uncommon thing, how-

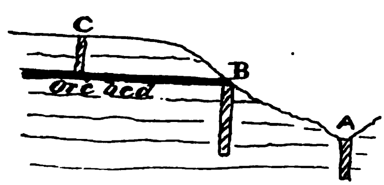


Fig. 88. Theoretic section showing different methods of prospecting for bedded deposits.

ever, to find the prospector sinking a shaft at the outcrop apparently on the theory that the ore there exposed is the upper end of a vein that runs straight downward. Often a shaft is put down at A, where the deeper it goes the further

it is from the ore body. In other cases a shaft is put down at C, where it must necessarily strike the ore bed, but by an unnecessarily expensive method. It should be remembered that many of the ore bodies of North Arkansas belong to this type, and once it is known that the ore is in such a bed there should be no hesitation about following it. In some portions of the zinc fields where the native miners have had no teachers save their own good sense, they have read the geology aright and have faithfully followed these outcrops.

Many drill holes have been put down in the zinc region, but many of the records are of no importance because the holes have been bored regardless of the fact that the rocks penetrated are all exposed in the sides of the hills near at hand.

It is necessary to say a word here in regard to what is called "going down"—a much mooted question in this region. The theory that zinc ore is to be looked for at considerable depths may be a perfectly correct one in some regions. Whether it is correct in this North Arkansas region depends on the precise location and the details of its geology.

Figure 1 on p. 18 shows the general features of the geology along the ridge northeast of Rush Creek.

Those who believe in the theory that paying ore deposits are to be expected only by shaft sinking, hold that the White Eagle property shown on this section is the only one in which ore is to be expected. But it is evident that the Morning Star mines, high on the hill, and the McIntosh mines, also on the hill though not quite so high, are on the same ore bed as the White Eagle in spite of the fact that the White Eagle gets its ore through a shaft below the level of Buffalo River.* Across Buffalo River from the White

* All three of these mines have vein deposits in addition to the bedded ores.

Eagle the ore bed is exposed again above water level—brought up apparently by a small fault.

Several claims along the north face of Hall Mountain near Yellville are high above the valley, and the ore occurs in some instances in two horizontal beds. A section through the mountains would be very like that shown in the accompanying cut. Now whether there is zinc ore be-

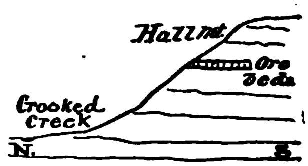


Fig. 89. Theoretic section from Crooked Creek southward through Hall Mountain.

neath the valley of Crooked Creek at the foot of this mountain I cannot say, but every one can see for himself whether or not a shaft or bore hole sunk in that valley would strike the ore beds near the top of Hall Mountain.

What is said above refers of course to the bedded deposits. In the vein deposits the method of prospecting must be determined in each case by local conditions, and

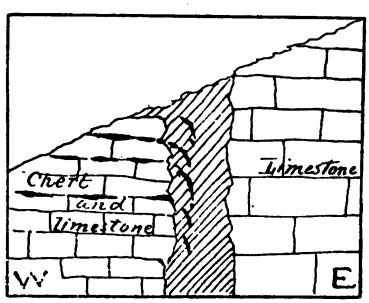


Fig. 90. Section at the Baker and McGrath shaft showing the faulted chert.

these conditions vary greatly. One of the ore deposits on the *Baker and McGrath* property in Newton County is in a vein having the structure here shown in Fig. 90. In this instance the miners have put down their shaft

on the vein—certainly a wiser procedure than to have left the vein on the hillside in order to sink a shaft in the bottom of the valley.

In another case near Boxley a vertical fractured zone running along the face of a hill has been entered by a tunnel driven in the hill as is shown in the accompanying illus-

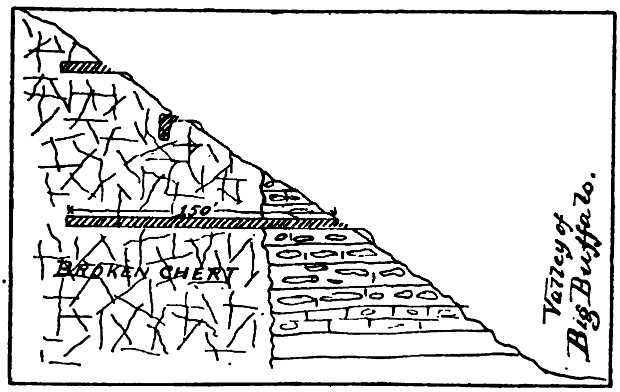


Fig. 91. Section at the Boxley tunnel.

tration. In this case again the ore body is not in the valley, and a shaft sunk there would not strike it.

The only thing that can be said in favor of sinking in the valleys is that if the ore occurs in the valley, the method is correct, otherwise it is not.

Every one who has followed the discussion of the origin and distribution of the ores given in Chapter II of this report can make his own rules in so far as rules worth having can be made. Inquiries are often made in regard to certain so-called rules laid down a few years ago for the guidance of the miners of this region.* One of these rules is "to follow the more prominent vertical fissures in the search for ore." Another statement, though not given in

* The lead and zinc deposits of the Mississippi Valley. By W. P. Jenney. Transactions American Institute Mining Engineers, 1893. XXII, 224 and 642.

the form of a rule,is of far-reaching importance, if it is true. It is that "all workable deposits of ore occur in direct association with faulting fissures traversing the strata, and with zones or beds of crushed and brecciated rock, produced by movements of disturbance the undisturbed rocks are everywhere barren of ore."

No fault is to be found with the statement that important ore bodies do occur in fissures, but to say that the ores occur *only* in fissures, and that "the undisturbed rocks are everywhere barren of ore," is to overlook many of the most important deposits of North Arkansas, that is, the bedded ones. Over a large part of the zinc region these ore beds can be traced as certainly as a coal bed in western Pennsylvania.

In regard to all these so-called rules, it is enough to say that the miners will do well to get their directions from the geology of the region in which they are working and not from the geology of some other state or some other country.

TRANSPORTATION.

Common roads.—The slow development of this part of the State has been due to geographic obstacles more perhaps than to any other one thing. These obstacles have existed from the earliest settlement of the country by white men. The first considerable number of white people to enter the State were French. They ascended the navigable streams to trade with the Indians, but they made but few journeys across the forest-covered regions of the Boston Mountains. Along the navigable streams, the Arkansas, the lower White River, these French settlers left here and there French names that have survived in one form or another to this day. It is an interesting and striking fact that these French names which are found through the southern and eastern parts of the State do not occur in the

northern part of Arkansas. The reason in all probability is that owing to the mountainous nature of the country and the absence of easily navigable streams this region was not penetrated by the French traders. Even now, when the region is well settled and the people are prosperous, the condition of the roads through most of the zinc regions is a serious obstacle to the development of the mines. Teaming over existing roads is next to impossible; the teams are killed off, the wagons are soon ruined, and the farmers who undertake the work cannot therefore earn fair wages for their work.

That the common roads are so bad is the more remarkable because there is probably no region in America, or in the world, where there is ready at hand such an abundance of the very best road-making material as we have in the broken and decayed Boone chert that lies scattered over the hills or strewn along the stream channels through the whole zinc region.

There is a certain disposition to imagine that the building of railways will do away with the necessity of good wagon roads. Nothing could be further from the truth. The zinc and lead mines of North Arkansas cover a large area, and the presence of railways will not do away with the necessity of a great deal of teaming in connection with the operation of the mines. I cannot therefore too strongly urge this matter of roads upon the people of North Arkansas. Such roads as we now have in this region would shut down 75 per cent. of the zinc mines now in operation in the United States. How can it be reasonably expected then that mines will be opened and kept in operation in the face of such an obstable? Nothing can be more unreasonable than to expect mines of the base metals to be profitable when the ores, in order to reach a market, must be hauled from 20 to 50 miles over mountain roads that would, in most parts of the world, be regarded as utterly impassable for teams.

Railways.—At the present writing (Oct., 1900) Eureka Springs—50 miles or more away—is the nearest market and railway for many of the zinc mines. Fortunately the Eureka Springs railway line is now being extended to Harrison, and is expected to be in operation by the time this report is printed.

Another line runs from Fayetteville on the St. Louis and San Francisco railway to Pettigrew in Madison County. Much zinc and lead ore and pig lead have been hauled from Newton County and shipped over this line. Most of the ore, however, that has gone out of North Arkansas has been hauled to some point on White River, shipped on barges down that stream either to Batesville or to Newport, where it is put on board cars for shipment to the furnaces further north.

Several proposed lines of railways have been surveyed through the zinc fields, and it is highly probable that some of them will be built in the near future.

Advantages and disadvantages.—Whether the zinc and lead deposits of North Arkansas can be worked at a profit under existing conditions of transportation cannot be regarded as determining the real value of those deposits. The most serious obstacle in the way of the development of the mine is the lack of railways and of good common roads. The railway problem is in a good way to be solved at an early day; the problem of the common roads is in the hands of the people, and if they are careful of their own interests they will solve it properly and without delay.

There can be no question about the existence of large bodies of excellent ore. There are, besides these richer deposits, many large bodies of low grade ores. Some of these are of course too poor to be worked economically under ordinary conditions, while others if worked upon a large scale will yield good returns.

So far as the extent of the ore deposits is concerned it is safe to say that it is so great that it is unknown. The

prospecting that has been done has not uncovered the hundredth part of the ore bodies. The bedded deposits have had their outcrops uncovered only here and there. A few pieces of the many fissures have been located, and these have been examined at but few points. The synclinal accumulations and the brecciated deposits are unknown save where they have been hit upon almost or quite by accident.

Some of the mines will be so high on the hills that there will never be much difficulty about draining them, but others will be in synclinal troughs and subterranean water courses where there will be much water to contend with.

In addition to the zinc and lead deposits there are many other mineral resources in the zinc regions that are untouched and almost unknown. The marble beds are unworked:—over hundreds of miles of outcrop there is not a single quarry, though some of these beds are as fine as any in Tennessee or Georgia. The glass sands of the saccharoidal sandstones have never been touched, in spite of the fact that these sands are quite as good as those of Missouri. The phosphate deposits have never been worked up and their distribution, extent and composition are practically unknown. The Mexican onyx, so abundant through the region, is not saved or utilized.*

The region is healthful, has a delightful climate, is abundantly supplied with timber and with the finest of water for milling and all other purposes. There is also an abundance of fruit and food supplies of all such kinds as are raised on farms in the southwest.

But though there seem to be many excellent opportunities for profitable mining in this region, I am not dis-

* We have seen beautiful pieces of this rock that would have brought high prices in the market wantonly destroyed, partly because the owners were not aware of its value, and partly because "this is a zinc mine—not a stone quarry."

posed to think that every one is capable of making a successful mine operator. Mining is more than blasting rocks out of the ground and selling them at so much a ton. Mining is a business like any other. It requires experience and skill in meeting and dealing with the many problems that are sure to arise in every undertaking of the kind. It should be remembered, too, that the ill effects of a failure to operate a mine in this region is not confined to the particular property concerned, but it retards the progress of the region as a whole. This would be less true if the development of the zinc mines had gone further than it has. If we had a large number of zinc mines in active and profitable operation, investors might attribute the failure of any given enterprise to mismanagement or to any other cause without its affecting their estimate of the value of the ore deposits in general. But for some time the failure of any enterprise must be expected to react to a greater or less extent upon every man in the zinc region. One of the fruitful sources of such failures is the employment by the mining companies of inexperienced superintendents. Already such employes have spent large sums of money for capitalists without any clear comprehension of the problems they have had to deal with. This is unfortunate for the companies furnishing the capital and also for the region that will have to bear the blame for such failures.

CHAPTER VI.

LIST OF THE MINERALS FOUND IN THE ZINC AND LEAD REGION OF NORTH ARKANSAS.

The following alphabetic list of minerals is made up mainly from the author's field and office notes, and makes no claim claim to completeness. In a region where the minerals have undergone so much alteration and where zinc and lead are so common, one might expect to find all the mineral forms of zinc, lead and iron. It is highly probable that such minerals occur, but no special search has been made for them, and it is probably for this reason that they are not here reported.

To make the list as interesting and useful as possible to those directly interested in mining, the popular names of the minerals are given and also their theoretic composition. It should be remembered, however, regarding this composition that all minerals are more or less impure, and, upon actual analysis, show, in small amounts, other contents than those given as the theoretic composition. For example the theoretic composition of sphalerite is 33 per cent. sulphur and 67 per cent. zinc. But if the analysis of any sphalerite be examined, it will be found that the actual composition is seldom or never that, but that it generally contains in addition a little iron, manganese or cadmium. (See analyses under the head of sphalerite.)

Alunogen, (hydrous aluminum sulphate; sulphur trioxide, 36.0; alumina, 15.3; water, 48.7 per cent.). Reported by Professor A. H. Purdue from Searcy County.

Anglesite, "dry bone," (lead sulphate: sulphur trioxide, 26.4; lead oxide, 73.6 per cent.). Associated with galena which it often encrusts.

Aragonite, "Mexican onyx," (carbon dioxide, 44; lime, 56). This mineral occurs in large quantities in several of the zinc mines.

Asphaltum, "pitch." Reported by Professor A. H. Purdue from Madison County.

Aurichalcite, (carbonate of zinc and copper: carbon dioxide, 16.1; zinc oxide, 53.2; cupric oxide, 20.8; water, 9.9 per cent.). Pale green, pearly translucent botryoidal masses usually about the size of a small pea or lining cavities. Common at many of the zinc mines, but always in small quantities; it is especially abundant at the Mud Hollow mines on Tomahawk Creek, Searcy County. Wherever the zinc blende crystals are being altered by weathering, especially where the change has left them an open, spongy, black mass, there are often small spherical greenish crystals of aurichalcite.

Anaylsis of aurichalcite from the "Famous" mine.

Zinc oxide	54.80 per cent.
Copper oxide	16.37 per cent.
Silica	5.72 per cent.
Ferric oxide	0.43 per cent.
Carbonic acid and water	21.72 per cent.

Azurite, (copper carbonate: carbon dioxide, 25.6; cupric oxide, 69.2; water, 5.2 per cent.). It occurs in beautiful blue masses, but sparingly at the copper mines on Tomahawk.

Brannerite. See smithsonite.

"Buck fat." See "Tallow clay."

Calamine, "dry bone," (silicate of zinc: silica, 25; zinc oxide, 67.5; water, 7.5 per cent.). Calamine is abundant at many of the zinc mines of the Sugar Orchard region. It is often confused with smithsonite with which it is frequently associated. Ton for ton, calamine is not as valuable an ore of zinc as smithsonite. The so-called "tallow clay" is a mixture of calamine and clay. (See analyses under "Tallow clay.")

Calcite, (carbonate of lime: carbon dioxide, 44; lime, 56 per cent.). Calcite is very abundant and occurs in many forms. The finest crystals of "dog-tooth spar" found in the region come from the White Eagle zinc mines at the mouth of Rush Creek, where they occur in soft red clay that fills cavities in the Ordovician rocks. "Nail head spar" is especially abundant at the Jackpot mine on Little Buffalo Creek, eight miles southwest of Jasper, Newton County.

Cerussite, "dry bone," (lead carbonate: carbon dioxide, 16.5; lead oxide, 83.5 per cent.). A white, cream colored or gray material associated with galena over which it often forms a coating. Found at the Big Elephant mines on Jimmy's Creek and at the Cutter mines in Newton County.

Chalcocite, "copper glance," (sulphide of copper: sulphur, 20.2; copper, 79.8 per cent.). Steel-gray or blackish. Reported by Professor A. H. Purdue from Carroll County.

Chalcopyrite, (copper pyrites, sulphide of copper and iron: sulphur, 35; copper, 34.5; iron, 30.5 per cent.). Brass-yellow, often iridescent. This mineral is found at many of the zinc mines, but only in small quantities.

Chrysocolla, (hydrous silicate of copper: silica, 34.3; copper oxide, 45.2; water, 20.5 per cent.). Blue and green translucent, small, globular crystals found in cavities at several of the zinc openings.

Copper, a little metallic copper was found at the Rossin shaft four miles east of Harrison. It has been found occasionally at other places, but always in small quantities.

Dolomite, "tiff," "pink spar," "rose spar," (carbonate of lime and magnesia: carbon dioxide, 47.8; lime, 30.4; magnesia, 21.7 per cent.). This mineral is associated with zinc blende at many of the mines, and especially at those where the sphalerite occurs in brecciated magnesian limestones or massive beds of dolomite. It is commonly looked upon by the miners as a "sign of ore."

Epsomite, "Epsom salt," (hydrous magnesium sulphate: sulphur trioxide, 32.5; magnesia, 16.3; water, 51.2 per cent.). Epsomite is found in the form of white hair-like crystals on the walls of several of the caves and in old mine tunnels. It is soluble in water and has a bitter taste.

Franklinite, (oxide of iron, zinc and manganese, varying much in composition. Individual analyses give from 7 to 23 per cent. of zinc oxide). This mineral was reported from the zinc district of Sharp County, but a chemical examination of the samples sent showed them to be limonite iron ore instead of franklinite. It is possible, however, that it may occur sparingly.

Galena, (lead sulphide: sulphur, 13.4; lead, 86.6 per cent.). This is the common ore of lead in north Arkansas, and it usually occurs in its characteristic cubical form. The following are analyses made of examples of galena:

	Big Elephant mine	Buffalo mine
Lead	84.72	86.02
Sulphur	13.89	13.80
Iron	0.52	trace
Silica	0.15	trace
Silver	0.00	0.00

Galena often contains silver, but out of a large number of specimens examined from the region under consideration none were found to contain any considerable amount of it. Silver has been reported by others, however, from the galena of North Arkansas.

Goslarite, (hydrous zinc sulphate: sulphur trioxide, 27.9; zinc oxide, 28.2; water, 43.9). Light yellow to brown, forming crusts and small stalactites in the zinc mines, especially in the old openings of Marion County. It has an astringent taste.

Greenockite (cadmium sulphide: sulphur, 22.3; cadmium, 77.7 per cent.).

Gypsum, "satin spar," (hydrous calcium sulphate: sulphur trioxide, 46.6; lime, 32.5; water, 20.9 per cent.). It occurs in broad crystals, fibrous and earthy.

Hematite, (iron sesquioxide: oxygen, 30; iron, 70). Iron in this form occurs sparingly all through the zinc regions. (See Annual Report of the Geological Survey of Arkansas for 1892, vol. II).

Hydrocerussite, (lead carbonate: carbon dioxide, 11.4; lead oxide, 86.3; water, 2.3). This mineral has not been positively identified in North Arkansas, but it is highly probable that some of the "dry bone" of the lead mines is hydrocerussite instead of cerussite.

Hydrozincite, "dry bone," (hydrous zinc carbonate: carbon dioxide, 13.6; zinc oxide, 75.3; water, 11.1). It is a white or cream-colored earthy deposit sometimes forming stalactites and encrusting other minerals and rocks. The mineral sometimes called "marionite" in North Arkansas is hydrozincite.

The following is the analysis of the so-called "marionite" as given by Elderhorst who proposed the name. This analysis shows that the older name hydrozincite has precedence.

Analysis of "Marionite" from North Arkansas.

Zinc oxide	78.26
Carbon dioxide	15.01
Water	11.81

Kaolinite, (Silica, 46.5; alumina, 39.5; water, 14.0.) This mineral occurs in small quantities at some of the zinc mines. There are said to be large deposits near Black Rock in 17 N., 1 W., section 7. A small sample from that place gave the following analysis:

Analysis of Kaolinite from North Arkansas.

Silica, SiO_2	47.98 per cent.
Alumina, Al_2O_3	37.47 per cent.
Iron, Fe_2O_3	1.89 per cent.
Lime, CaO	0.10 per cent.
Potash, K_2O	0 48 per cent.
Soda, Na_2O	0.29 per cent.
Water, H_2O	13 87 per cent.

Limonite, (hydrous oxide of iron: oxygen, 25.7; iron, 49.8; water, 14.5). Limonite iron ore is abundant in Sharp, Lawrence, Fulton and Carroll counties. (See Ann. Rep. Geol. Surv. of Ark., 1892, vol. I.) It is often found as a pseudomorph after pyrites.

Malachite, (copper carbonate: carbon dioxide, 19.9; cupric oxide, 71.9; water, 8.2 per cent.). Bright green earthy and crystalline masses. Tomahawk copper mines, Searcy County. Two assays of malachite from this locality gave 39.48 and 39.57 per cent. of metallic copper. It is found in small quantities at several of the zinc mines.

Marcasite, "mundic," (iron disulphide: sulphur, 53.4; iron, 46.6); very like pyrites; bronze yellow color; decomposing more readily than pyrites; it is occasionally found in the zinc mines in the form of small stalactites.

Newtonite, (hydrous silicate of alumina: silica, 38.5; alumina, 32.7; water, 28.8 per cent.). A white soft powder found as balls in clay on Sneed's Creek, Newton County. This is a new mineral discovered by the Geological Survey of Arkansas. The description has not been published hitherto in the Survey's reports, and it is therefore given here in full.*

"The first compound which will be described, and that which suggests the series given above, is found on Sneed's Creek in the northern part of Newton County (16 N., 23 W., section 1), in the State of Arkansas. At this place a mineral claim was laid and a shaft opened in 1889 by Mr. W. S. Allen, of Harrison, Ark. The rocks of the region are for the most part sandstones and shales of the Barren Coal Measures, while the opening itself seems to penetrate some of the limestones of the Lower Carboniferous series. At a depth of 8 feet this form of kaolin was found imbedded in

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* Newtonite and Rectorite—two new minerals of the Kaolinite group. By R. N. Brackett and J. F. Williams. American Journal Science, July, 1891, XLII, 13-16.

a dark gray clay, through which it is scattered in lumps which vary from a few ounces to 40 pounds in weight. Iron and a little manganese also occur in the opening. Samples of the material were kindly furnished the Geological Survey of Arkansas by Mr. Allen, the proprietor of the claim.

"On account of its occurrence in Newton County we propose the name *Newtonite* for this, the fourth member of the Kaolinite series.

"Newtonite is a pure white, soft, compact, homogeneous substance, and both chemical analysis and microscopic examination show it to be remarkably pure substance. It is infusible before the blowpipe, and when in the form of a powder it has a specific gravity of 2.37. It is only slightly attacked by boiling concentrated hydrochloric acid, but boiling concentrated sulphuric acid decomposes it almost completely, with a separation of silica. It is also decomposed by a boiling saturated solution of caustic potash with the formation of a compound insoluble in water but easily soluble in cold dilute hydrochloric acid. (See below.)

"Quantitative chemical analyses of newtonite gave the following results:

	No. I	No. II
SiO_2	38.86	40 22
Al_2O_3	35.20	35.27
Loss on ignition	23.69	22.89
Fe_2O_3	0 21	0.21
CaO	0.31	0.54
MgO	trace	trace
K_2O	1.73*	0 99
Na_2O		0.73
	100.00	100.85
Water at 110°-115° C	5.53	5.44

"If the impurities be disregarded and the silica, alumina and loss on ignition in analysis I be recalculated to 100

* Alkalies by difference.

per cent., and the same is done in II, after bringing the whole to 100 per cent., the following figures are obtained:

	No. Ia	No. IIa	Theor. For. Al_2O_3. $2SiO_2$. $4H_2O$.
SiO_2	39.76	40.88	40.82
Al_2O_3	36.01	35.85	34.72
Loss on ignition	24 23	23.27	24.46
	100.00	100.00	100.00

"Although this compound closely resembles ordinary kaolin in its chemical properties, it shows thus a marked difference in composition, by containing for the same amount of silica and alumina double the quantity of water usually found in kaolin.

"That an apparent similarity exists between newtonite and halloysite when a comparison is instituted between the analysis of newtonite calculated on the material dried at 110 degrees and the published analyses of halloysite where it is not stated whether the calculations are made on the air-dried material or that dried at the abovementioned temperatures, is shown in the following table:

	Newtonite		Halloysite (Indianaite)	
	No. Ia	No. IIa	No. III	No. IV
SiO_2	39.76	40.882	39 85	38.90
Al_2O_3	36.01	35.851	36.85	37 40
Loss on ignition	24.23	23.267	22.90	23.60
	100.00	100.000	98.60	99.90
			.40 CaO	
			99.00	

"Analysis III is of a soft and IV of a hard, white variety of halloysite called indianaite.* H. Pemberton, Jr., who made these analyses, kindly furnished the information that the calculations are made on the *air-dried material*, and that in analysis III, 8.68 per cent. of the loss on ignition is given off at about 110 degrees C.

* Report of the Geological Survey of Indiana, 8th, 9th and 10th Annual Reports (1876-1878), p. 156. See also Sixth Annual Report (1874), p. 15.

"If analyses Ia and IIa be calculated to the air-dried material the difference between them and the published analyses of halloysite is clearly shown, as is evident from a consideration of the following table:

	No. Ib	No. IIb	Halloysite
SiO_2	36.83	37.96	39.35
Al_2O_3	33.42	33.34	36.35
Loss on ignition	24.22	23.26	14.22
Water at 110°-115° C	5.53	5.44	8.68 (at 100° C)
	100.00	100.00	98.60

"If it be assumed that the 8.68 per cent. of water in halloysite is partly hygroscopic and partly water of crystallization, this mineral would have the composition of kaolinite containing one molecule of water of crystallization. Judging from the newtonite analyses Ib and IIb, this substance would, under like circumstances, have one molecule of water of crystallization, but would be represented by the formula $Al_2O_3.\ 2SiO_2.\ 4H_2O+$ aq, while the composition of halloysite would be expressed by the ofrmula $Al_2O_3.\ 2SiO_2.\ 2H_2O+$ aq.

"Ordinary kaolin usually contains less than 1 per cent. of loosely combined water. Hydrous silicates of alumina have, however, been analyzed in this laboratory, which have given off as much as 5 per cent. of water at 110 degrees C., but which differ from ordinary kaolin in no other respect, and it is probable that differences in origin and occurrence will account for these varying amounts of *loosely combined* water.

"A thin section of newtonite under the microscope when viewed only with low powers appears as a perfectly amorphous substance but when magnified to 400 or 500 diameters it shows that it is entirely made up of minute rhombs or squares. The largest of these are not more than 0.005 mm ($\frac{1}{5000}$ of an inch) on an edge, while the smallest appear to be about half that size. Sometimes they seem to form perfect squares but in the majority of

cases the acute angles have values ranging from 88 degrees to 89 degrees, as nearly as could be measured. There appear between these minute figures blank spaces where nothing can at first be seen, but by sinking the microscope tube somewhat, so as to focus a little lower down, an entirely new set of rhombs is discovered, while those above go out of focus. At first sight all the rhombs appear as squares and show small indistinct lines running from their corners toward the center, giving the appearance of the hopper-shaped crystals of salt. In addition to this there is a white rim about the edges which gives them the appearance of being higher than the rest of the surface. The cause of this is, however, not due to any marking or relief on the surface but probably to internal reflections whose origin it is hard to detect.

"In polarized lights the rhombs extinguish sharply parallel to their diagonals, thus showing that they are faces of some anistropic material and not, as might be supposed, sections of the cubes which had been cut more or less obliquely.

"If these rhombs and squares are sections of rhombohedrons then one would expect to find also plane triangles corresponding to sections perpendicular to the principal axis. This, however, is not the case and only in a very few instances have any triangular forms been found and even then they are very indistinct and appear not to be in the upper surface of the plate but somewhat lower down. It is probable that in making sections of this material the individual crystals are not cut, but are either rubbed away entirely, or are left undisturbed, so that what are seen under the microscope are not sections but crystal faces. By means of a selenite plate the positions of the axes of greatest and least elasticity were determined, and were found to lie respectively parallel to the shorter and longer diagonals of the rhomb.

"By powdering some of the material and allowing it to settle out from water, similar rhombohedral crystals were obtained."

Niter, "saltpeter." The so-called niter earth occurs in the dry caverns through the limestone regions of North Arkansas. The following is the composition of a specimen of this earth as given by Dr. Owen.*

Analysis of niter earth from Bean's Cave or Rock House.

Hygrometric water	3.15	per cent.
Silicates, etc	64.68	per cent.
Alumina	10.00	per cent.
Peroxide of iron	7.68	per cent.
Lime	3.65	per cent.
Magnesia	1.50	per cent.
Potash	0.945	per cent.
Soda	0.650	per cent.
Manganase	0.080	per cent.
Sulphuric acid	0.860	per cent.
Phosphoric acid	0.015	per cent.
Carbonic acid	0.050	per cent.
Chlorine	0.198	per cent.
Organic matter, water and ammonia	2.428	per cent.
Nitric acid and loss	4.614	per cent.
	100.000	per cent.

Opal, var. *tripoli*, which see.

Phosphate rock. The phosphate rock is not a definite mineral, but its composition is sufficiently constant to warrant its mention in this list. It occurs on the Garvin tract on Monkey Run near the town of St. Joe, Searcy County, where it forms a bed at the top of the Silurian rocks. This bed is characterized by an abundance of black shiny nodules. A similar but richer bed is exposed on Tomahawk Creek on the land of Leonard Keeling.

Analyses of phosphate nodules.

	Monkey Run	St. Joe	Keeling's
Phosphoric acid, P_2O_5	25.92	31.75	35.11
Equivalent to bone phosphate	56.58	69.31	76 72
Oxide of iron and alumina	9.01	8.10	7.21

* First report of a geological reconnoissance. By D. D. Owen, p. 54. Little Rock, 1858.

The phosphate beds probably occur at intervals across the entire northern breadth of the State. They have been seen at several points, but no attempt has been made to locate the profitable places. Besides those above mentioned these beds are well exposed in the vicinity of the manganese mines near Cushman, and also near Hickory Valley, 12 miles north of Batesville on what is known as the Milligan place.

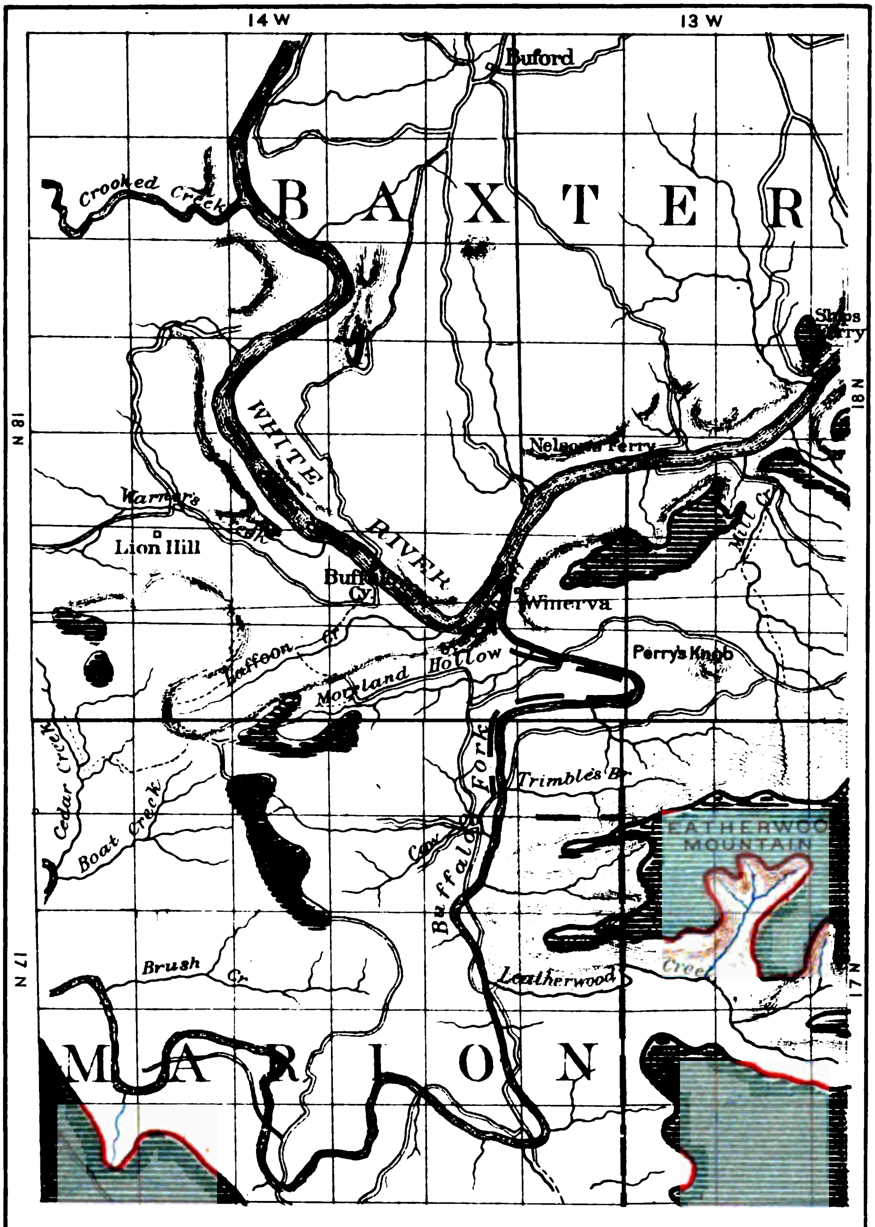
Analysis of phosphate rock from the Milligan place.

	per cent.	per cent	per cent.	per cent.	per cent.	per cent.
Phosphoric acid, P_2O_5	26.18	26.77	29.40	29.98	31.06	31.11
Equivalent to bone phosphate, $Ca_3P_2O_8$	51.53	52.08	64.82	65.57	67.21	67.74
Iron and alumina	5.89	5.86	3.08	3.87	8 01	7.05

Pyrite, "fool's gold," "mundic," (iron disulphide: sulphur, 53.4; iron, 46.6 per cent.). Brass yellow, often in cubes, sometimes massive. Iron pyrites is found in small quantities at a few of the zinc mines. Even when not otherwise noticeable it betrays its presence after weathering on the ore-heaps by staining the rocks in which it occurs a dark reddish brown or rusty color. On Keeling's place, Tomahawk Creek, Searcy County, there is a bed of iron pyrites at the contact between the Silurian and Carboniferous rocks from 3 to 10 inches thick. It is a valuable ore when found in quantity, but it is regarded as a detriment to zinc when mixed with its ores.

Psilomelane, (hydrous oxide of manganese of varying composition). This is the common steel gray ore of manganese. The famous manganese mines of Independence County are a short distance south of the zinc district of Sharp and Lawrence counties. This mineral is sometimes found in the zinc region proper, but only in small quantities.*

* On manganese in Arkansas, see Manganese. By R. A. F. Penrose, Jr. Annual Report of the Geological Survey of Arkansas for 1890, vol. I.



GEOLOGY ABOUT BUFFALO CITY.

Scale: 1 inch = 2 Miles

0 ¼ ½ ¾ 1 2 3 4 5 MILES

0 1 2 3 4 5 6 7 8 KILOMETRES

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Pyrolusite, (manganese dioxide). An important ore of manganese, but less abundant than psilomelane. It occurs in small quantities associated with the psilomelane. It is of a steel gray color and soft enough to soil the fingers.

Pyromorphite, "dry bone," (lead phosphate: lead phosphate, 89.7; lead chloride, 10.3 per cent.). Earthy, encrusting variety covering cubes of galena, found in the Buffalo or Tallow Clay mine, 20 N., 18 W., section 35, southwest of the southeast.

Analysis of pyromorphite from the Buffalo or Tallow Clay mine.

Lead oxide, PbO	71.28
Lime, CaO	6.20
Phosphoric acid, P_2O_5	16.61
Chlorine, Cl	2.25
Carbonic acid, CO_2	1.74
Silica, SiO_2	0.22
Water combined, H_2O	0.86
Iron and alumina, Fe_2O_3 and Al_2O_3	0.88
Magnesia, MgO	trace
	99.49

Pyrophyllite, "pencil stone," (silica, 66.7; alumina, 28.3; water, 5 per cent.). Reported by Professor A. H. Purdue from Newton County.

Quartz, "crystal," (Silica: oxygen, 53.3; silicon, 46.7). Although there are no mineral-bearing quartz veins in North Arkansas, there is an abundance of quartz crystals in some of the zinc mines. In some instances cavities in the rocks are beautifully coated with quartz crystals.

Smithsonite, "dry bone," (zinc carbonate: carbon dioxide, 35.2; zinc protoxide, 64.8 per cent.). This is the most valuable, and, next to sphalerite, the most abundant ore of zinc in North Arkansas. It occurs in many forms and of many colors.

Analyses of smithsonite.

	Morning Star mine	Legal Tender mine
Zinc oxide, ZnO	64.81	62.20
Carbon dioxide, CO_2	34.98	33.86
Water, H_2O	0.56	2.30
Silica, SiO_2	0.10	0.02
Magnesia, MgO	0.08	0.18
Lime, CaO	0.90	1.25
Iron and alumina, Fe_2O_3 and Al_2O_3	0.12	0.21
Cadmium, Cd	trace	trace

The beautiful yellow ore found at many of the zinc mines and popularly known as "turkey fat" is smithsonite stained with a little cadmium sulphide.

Analysis of "turkey fat," a yellow variety of smithsonite.

	Morning Star mines	
Zinc oxide, ZnO	63.84	61.20
Carbon dioxide, CO_2	34.60	......
Water, H_2O	1.09	......
Silica, SiO_2	0.25	......
Magnesia, MgO	0.07	......
Lime, CaO	0.70	......
Cadmium oxide, CdO	0.90	0.82
Iron and alumina, Fe_2O_3; Al_2O_3	0.42	......

Sometimes smithsonite occurs as a red, yellow or brown "sand;" the particles in such cases are small, loose crystals of zinc carbonate.

A certain zinc mineral that has been called "*brannerite*" by Mr. W. A. Chapman, of Smithville, Ark., is not a new mineral as Mr. Chapman supposed, but a mixture of smithsonite with something else. Specimens of the so-called "brannerite" from Coon Hollow, Boone County, Arkansas, sent me by Mr. Chapman as typical examples were analyzed with the following result:

Analyses of a variety of smithsonite.

	No. I	No. II
Carbon dioxide, CO_2	32.82	32.82
Silicia, SiO_2	0.22	0.24
Iron, Fe	0.82	0.35
Copper, Cu	0.79	0.78
Moisture, H_2O	0.16	0.12
Combined water, H_2O	2.18	2.18
Zinc, Zn	63.87	64.41
	100.86	100.90

I thought at first that this mineral was hydrozincite, but the percentage of water in it was evidently too small. These analyses were therefore submitted to Professor Samuel L. Penfield, of Yale University, with a request for his opinion in regard to the classification of the mineral. Professor Penfield writes:

"The analysis indicates a mixture of smithsonite with some other mineral. The amount of water is too small to belong to any one mineral of the carbonate group."

Sphalerite, "jack, rosin jack, ruby jack, black jack, blende." (Zinc sulphide: sulphur, 33; zinc, 67 per cent.). This is the most abundant and most important ore of zinc found in north Arkansas. It occurs in bedded deposits, and also filling the fractures of breccias, and in small veins that break across the rocks. It is most abundant in the Silurian and Ordovician rocks but it is also found in fractures that cross rocks of Lower Carboniferous age.

Analyses of sphalerite from North Arkansas.

	Yankee Boy mine	Hiawatha mine	Gov. Eagle mine	Panther Creek mine
Zinc, Zn	65.88	66.27	64.48	65.88
Sulphur, S	31.77	32.53	32.16	32.30
Silica, SiO_2	0.10	0.21	1.88	0.00
Iron, Fe_2O_3	0.62	0.39	0.26	0.49
Magnesia, MgO	0.14	trace	0.00	trace

	St. Joe mines	Bear Hill mine	Prince Frederic mine
Zinc, Zn	65.73	66.46	65.68
Sulphur, S	32.92	32.30	33.33
Silica, SiO_2	0.11	0.25	0.09
Iron, Fe_2O_3	0.15	0.15	0.15
Magnesia, MgO	0.08	0.20	0.08
Lime, CaO	0.50	0.51	0.25

These analyses show the sphalerite of North Arkansas to be remarkably pure.

Strontianite, (strontium carbonate: carbon dioxide, 29.9; strontia, 70.1 per cent.). This mineral is mentioned

here on the authority of W. Albert Chapman, of Smithville, who reports it from Rush Creek, Marion County.

Sulphur.—Sulphur occurs in small crystals in the upper opening of the Silver Hollow mines on the east bank of Buffalo River below the mouth of Rush Creek, at the opening on the bed of iron pyrites on the Keeling place on Tomahawk Creek, and at a few other places where small quantities of pyrites are exposed.

"Tallow clay," called "buck fat" in the zinc mines of Tennessee and Virginia. This is not a definite mineral, and, in so far as it can be classified from its composition, it belongs with the mineral *calamine,* but with the calamine is mixed a good deal of clay with which belong the iron and other impurities usually found in common clay. The following analyses show its varying composition:

Analyses of tallow clays.

	Buffalo mine	Big Elephant mine	Post Boy mine	Coon Hollow mine	Kansas mine	Markle mine
Silica, SiO_2	51.08	45.10	40.91	87.04	41.67	36.65
Alumina, Al_2O_3	16.98	16.52	9.83	8.85	8.47	10.05
Zinc oxide, ZnO	14.10	18.97	84.79	87.76	85.88	87.54
Ferric oxide, Fe_2O_3	5.98	5 65	2.25	1.68	2 85	2.86
Ferrous oxide, FeO	0.69	8.16	0.52	0.42	0.83	0.58
Lime, CaO	1.16	2.70	8.42	8.58	1.86	2.20
Magnesia, MgO	1.84	1.58	0.48	0.77	0.51	1.62
Potash, K_2O	0.44	1.15	......	0.27	0.57	0.85
Soda, Na_2O	0.00	0.62	0.42	0.56	0.07	0.40
Water, H_2O....................	8.88	10.89	9.02	3.76	8.28	8.92

Other analyses are given under the descriptions of the mines.

The high percentage of zinc in these clays ought to give them some value as zinc ores, but at present the difficulty of smelting them makes it impossible to market the tallow clay.

"Turkey fat," see smithsonite.

"Tripoli" is said to be a form of opal. In composition it is nearly pure silica. The "tripoli" of commerce found

in North Arkansas is derived from chert or flint by the process of weathering. There is a great abundance of this material in the zinc region, but whether or not it has any commercial value is a matter that can be determined only by experiment. It is extensively used for manufacturing polishing powders and water filters. The following analysis was made of the "tripoli" from Seneca, Missouri:

Analysis of "tripoli."

Silica, SiO_2	98.28 per cent.
Alumina, Al_2O_3	0.17 per cent.
Ferric oxide, Fe_2O_3	0.58 per cent.
Lime, CaO	trace
Potash, K_2O	0.17 per cent.
Soda, Na_2O	0.27 per cent.
Loss on ignition, H_2O	0.50 per cent.
	99.92 per cent.
Water at 110°-115° C	0.21 per cent.

Wad or bog manganese is of common occurrence, but it is not a mineral of any especial interest or importance in this connection.

Zincite, (zinc oxide: oxygen, 19.7; zinc, 80.3 per cent.). Red or yellow mineral. It occurs in very small quantities at the Morning Star mine and at the Silver Hollow mine in Marion County.

CHAPTER VII.

THE PALEOZOIC FAUNAS OF NORTHERN ARKANSAS.

By Henry Shaler Williams.*

Introduction.—The fossils reported upon in the following pages, were originally collected for the purpose of identifying the geological age of the formations from which they came, and were sent to the writer by Dr. John C. Branner, then State Geologist of Arkansas, and upon examination the conclusions reached from their study were communicated by letter to Dr. Branner, who incorporated whatever was of immediate use directly in the reports of the Survey as they were published.†

As time progressed, several interesting faunas were elaborated, and, through the assistance of the United States Geological Survey, collectors were sent into the field and the original collections were thus enlarged. Thus the collecting of the material was distributed among the following men: Dr. Branner and his assistants of the Arkansas Survey; Mr. Penrose and Mr. Hopkins; and through the agency of the United States Geological Survey, Mr. Gilbert Van Ingen, Mr. Stuart Weller and the writer.

The original indentification of the material was made by the writer as the material was received, and reports of the results of this preliminary study were sent directly to

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* By permission of the Director of the U. S. Geological Survey.

† Ann. Reports, Geological Survey of Arkansas. By John C. Branner, Ph. D., state geologist, for 1888. four volumes, 1889 vol. II, 1890 vols. I, IV, 1891 vols. I, II, 1892 vols. I, II.

Dr. Branner, as above stated; but no separate formal report of these results was published, the hope having been entertained that a final report on the Paleontology of the State would be published by the State. After some negotiations, it became evident that this plan was not practicable, and the materials and manuscript reports were held for some other mode of publication.

In the mean time, parts of the collections were made the subject of exhaustive study by Mr. Gilbert Van Ingen and Mr. Stuart Weller, then pursuing special studies in paleontology under my direction at Cornell University and later at Yale University. Much assistance was rendered by these gentlemen in preparing the specimens, and thoroughly identifying and labeling the species; although in almost every case the identification of species was originally made by me and notes recorded regarding the faunas, the peculiarities of the species, and their relations to other species, these gentlemen did much of the work of sorting out the specimens, and, in several cases, first called my attention to species which had not been previously detected. Mr. Van Ingen did the great bulk of the work of identifying the beautiful fauna of small species in the Spring-creek limestone. Mr. Weller did a large part of the work of compiling the specific synonomy* and in clerically putting together the notes which had been accumulated during the whole series of studies. A small salary paid these assistants by the U. S. Geological Survey enabled me to put these collections in a fine state of elaboration, and to detect every species which the faunas then contained.

Upon the request of Dr. J. C. Branner, State Geologist of Arkansas, I undertook in 1888 and 1889 the determination of the geological horizons indicated by fossils col-

* See Stuart Weller, A Bibliographic index of North American Carboniferous Invertebrates. Bulletin No. 153, U. S. Geological Survey, pp. 1-653. 1898.

lected by members of the State Survey. The fossils were few and often in imperfect condition, but in most cases were sufficient for the purpose of indicating the geological horizon. In 1889 arrangements were made to have the paleontological determinations of the fossils, collected by the Arkansas Survey, done by the members of the U. S. Geological Survey. I was at the time engaged in accumulating facts regarding the Devonian and Carboniferous faunas of the Mississippi valley, under the auspices of the U. S. Geological Survey, and since 1889 was in frequent correspondence with Dr. Branner regarding the determinations made by me in the above capacity, reporting, as the fossils came to sight, the formation indicated by the fossils. In December, 1890, I sent in a detailed report, based upon these studies, of the peculiarities in the stratigraphical sequence of formations, to Dr. Branner.

On account of apparent confliction between the interpretation of the stratigraphy made by the field observers and the interpretation suggested by my study of the fossils, I went to Arkansas in August, 1890, and traversed the ground with Dr. Branner, confirming the fact of sudden and great change in the paleontological horizons, in several places where the lithological characters of the rocks and the stratigraphy offered little and often obscure evidence of the fact. Although our examination was rapid and very few additional fossils were accumulated, the great importance of the *Devonian interval,* as it may be called, was clearly established. The course traversed was from Batesville westward, across country, to Eureka Springs. The best expression of the details of the interval were seen at St. Joe, where, without apparent unconformity of strata, the Silurian limestone is separated by a few feet of green shale and nodular sandstone, called Sylamore sandstone, from the Carboniferous limestone. In this place the lower limestone has a light cream color, and the

Carboniferous a strong red color, running up into a lighter pink, and still higher, a light cream color; but in several places the Silurian limestone next below the interval is also pink or reddish in color, as at Polk Bayou in Independence County. During the summer of 1891, in order to get fuller collections of fossils, to interpret the facts regarding the erosion and other geological events expressed in this interval, Mr. Stuart Weller was sent at the expense of the United States Geological Survey, over the same ground. He was accompanied by Mr. Hopkins, of the Arkansas Survey, and they collected fossils and noted, particularly, the details of the stratigraphical disposition of sediments across this interval at as many stations as was practicable. Collections bearing upon the same problem were also made on the west and east sides of the Ozark uplift in Missouri and adjoining states by Mr. W. P. Jenney, while studying the zinc and lead deposits, and by Mr. Gilbert Van Ingen, employed by the U. S. Geological Survey for that specific purpose, and by Mr. Weller. The expenses of making these collections, and that involved in their study by these gentlemen, were borne by the U. S. Geological Survey; and the detailed descriptions of new species and the discussion of the relations of variations and mutations of species now known with the needed illustrations were carried on afterwards.

During the year 1892 the work was greatly delayed, except as carried on at private expense, on account of the restrictions placed upon the paleontological work of the U. S. Geological Survey. No funds were available from the State for paleontological work on the Arkansas State Survey, and therefore the United States Geological Survey should be credited with whatever benefit the State survey may have received or does receive from the paleontological determinations, and the clearing up of the interpretation of the stratigraphical relations of the formations of Northern Arkansas.

The following summary of the more important results is offered as a preliminary report upon the paleontology of this interesting region, and the description, illustration and discussion of the new or more interesting fossils obtained is reserved for publication in separate form.

The rocks of Northern Arkansas are in general upper Paleozoic deposits laid upon the southern flanks of the great Ozark uplift centering in southern Missouri. The great mass of the whole foundation rock-terrane is, so far as it reaches the surface in Arkansas, of Eopaleozoic age, ranging from Calciferous to Niagara. The elevation of the region in Neopaleozoic time is indicated by the great variation in the terminal Silurian formation at the point of greatest break in the series. The resumption of deposition as indicated by the fossils was in Neodevonian, or Eocarboniferous time. The great break in the series has for its underlying formation Calciferous, Trenton or Niagara rocks, and not till the corner of Illinois is reached, on the northeast, are higher Silurian formations found below the interval. Above the break, considering the irregular interval filling deposit as a member by itself, the first faunas to appear are Carboniferous, ranging from early Chouteau to the Coal Measures.

Geological section of Northern Arkansas.

The latest published revision of the geological section of Arkansas, I find in a paper* by the State Geologist, Dr. J. C. Branner, read before the American Institute of Mining Engineers, in September, 1896. The section is as follows, and is based upon the rocks appearing north of the Boston Mountains:

* The Phosphate Deposits of Arkansas. Am. Inst. Min. Eng., Sept. 1896.

		Maximum thickness in feet
Coal measures of Pennsylvania in the top of the Boston Mountains and their outliers.		
Lower Carboniferous or Mississippian	Boston group shales, limestones, sandstones, cherts	780
	Batesville sandstone	200
	Fayetteville shale	300
	Boone chert and limestone	370
Devonian (?) (phosphate horizon)	Sylamore sandstone	40
	Eureka shale	50
Lower Silurian	St. Clair marble*	155
	Izard limestone	285
	Saccharoidal sandstone, Magnesian limestone, Sandstones, cherts, etc.	1750+

The foot-note, indicated by the star after the St. Clair marble, refers to my paper in American Journal of Science as asserting that the upper part of the St. Clair is upper Silurian. This will give me the occasion to modify the section so as to put in place of "St. Clair marble, 155 feet," the following corrected section:

Upper Silurian (Manganese deposit)	St. Clair marble (restricted sense) H. S. W.	155
	Cason shale, H. S. W.	
	Polk Bayou limestone, H. S. W.	
Lower Silurian	Izard limestone	285
	Saccharoidal sandstone, Magnesian limestones, Sandstones, cherts, etc	1750+

The reason for this amendment of Dr. Branner's section will be given beyond. The discussion of the several formations and of the fossil faunas will follow the classification here presented.

The names, St. Clair marble and Polk Bayou limestone, were both proposed by Dr. Branner early in our correspondence, and the only name for which I am responsible is Cason shale. This was given in the paper above referred to* in 1894.

The following elaboration of the classification as it appears in the various annual reports was compiled by Mr. Stuart Weller:

* Am. Jour. Sci., 3d Ser., 1894, XLVIII, 326.

Paleozoic Divisions of Arkansas.

(As recognized in the published reports of the Arkansas Geological Survey, and compiled by Stuart Weller; arranged in descending order).

Coal Measures (Pennsylvanian).		
Millstone grit.		
	Boston group (Branner) Genevieve (H. S. W.) =Chester, St. Louis and Warsaw (H. S. W.)	Kessler limestone Coal-bearing shale Pentremital limestone Washington shale and sandstone Archimedes limestone (Shaly sandstones) Marshall shale
	Osage group (H. S. W.) =Keokuk and Burlington (H. S. W.)	Batesville sandstone Fayetteville shale Wyman sand tone Boone chert St. Joe marble
	Choteau ? (H. S. W.) Black shale of Tenn. (H. S. W.)	Sylamore sandstone
Devonian ?	Black shale (Branner) Lower Carb. (H. S. W.)	Eureka shale
Silurian and Ordovician	Between Trenton and Niagara (H. S. W.)	St. Clair limestone
	Calciferous (H. S. W.)	Izard limestone Saccharoidal sandstone Magnesian limestone Chert Sandstones, etc.

Millstone Grit, (IV, 196, 1888; I, 140, 1890) underlies Coal Measures of Arkansas Valley, just above Kessler Limestone. Layers of shales and sandstones. Caps Boston Mountains and elsewhere. Determined by Owen, 1858.

Kessler Limestone, (IV, 103, 1888) occurs in thin layers in region around Kessler Mountain, from which it was named by Simonds.

Coal Bearing Shale, (IV, 93, 1888) situated between Kessler limestone and Pentremital limestone. It is argillaceous—blue, black, gray—and fossiliferous (Many plants, a few spiders). Is widely distributed; and is a source of coal (veins about one foot or less). Named by Simonds.

Pentremital Limestone, (IV, 83, 1888; IV, 91, 1890) fossiliferous, hard, gray, enters largely into the bench topography of the country—impure, loose and of little

value; 90 feet thick in Washington County; found also in Madison County and elsewhere. Named by Simonds from great abundance of Pentremites.

Washington Shale and Sandstone, (IV, 75, 1888) is the filling of varying thickness between Archimedes and Pentremital limestones; Lepidodendron and other fossils occur in sandstone. Found in Washington County, and named by Simonds from Washington Mountain, where these beds are exposed.

Archimedes Limestone, (IV, 55-74, 1888; IV, 92, 1890) of light-gray color, fossiliferous, 25 feet to 40 feet thick, generally speaking. Important topographic feature. Widely distributed, impure. Named by Simonds from the presence of numerous Archimedes fossils.

Marshall Shale, (IV, 53, 1888) is a black, more or less bituminous shale, distinguished by its position, between Archimedes limestones and Batesville sandstone, unimportant or wanting. Named by Branner from the shale mountain, east of Marshall, Stone County.

Batesville sandstone, (IV, 49, 1888; I, 139, 1890; II, 51, 1891) immediately beneath Archimedes limestone, or with Marshall shale between them. Is coarse—gray to brown—or fine; 20 feet to 200 feet thick; widely distributed. Named from Batesville, Arkansas, by Branner.

Fayetteville Shale, (IV, 42, 1888; I, 138, 1890; II, 50, 1891) just above Boone chert, or with Wyman sandstone between; black or gray shales, with thin beds of siliceous black limestone and sandstone; highly siliceous. Same distribution as Batesville sandstone, and intimately associated with it. Washington County and elsewhere. Named by Simonds from Fayetteville, where it is well developed.

Wyman Sandstone, (IV, 38, 1888; II, 46, 1891) few exposures of soft, yellowish-brown sandstone, from widely separated localities. Found between Boone chert and

Fayetteville shale in Washington County. Named by Simonds from Wyman, Washington County.

Boone Chert (IV, 27, 1888; I, 129, 1890; IV, 94, 1890; II, 38, 1891) cherts and cherty limestone at base of Carboniferous in northern Arkansas, fossiliferous. Varies greatly. Widely distributed; named from Boone County, by Branner.

St. Joe Marble, (IV, 253, 1890) red limestone north of Boston Mountains, "fossils belong to Burlington," "the entire Chert series, of which St. Joe Marble is part, includes the Burlington limestone (of Hall) of Iowa and Keokuk." (H. S. W.) In nearly all northern counties. Named from St. Joe, Arkansas, by Branner.

Sylamore Sandstone, (I, 114, 1890; IV, 212, 1890) generally an insignificant bed of varying composition (of round grains of crystalline quartz, with pebbles and concretions, arenaceous, soft) and thickness (less than 40 feet usually thin). Rests on Eureka shale, St. Clair limestone, or Izard limestone. Stone County, etc. (Named from Sylamore Creek by Branner, I, 114, 1890.)

Eureka Shale, (IV, 26, 1888; IV, 213, 1890; II, 31, 1891) a fine grained, thin bedded black shale. Named by Branner from Eureka Springs.

St. Clair Limestone, (I, 112, 124, 1890; IV, 212, 1890) Top member of Silurian rocks and is below Sylamore, or Eureka, or Boone chert; fossiliferous, light-gray to brown, highly crystalline, maximum thickness 150 feet. Along White River, Buffalo River, etc. Between Trenton and Niagara (H. S. W.). Named from St. Clair Springs by Branner. (See this report, p.285, for further elaboration of this formation, H. S. W.)

Izard Limestone, (I, 121, 1890; IV, 108, 1890) below St. Clair and above Saccharoidal sandstone (Calciferous, H .S. W.)—dark-blue, gray, black, valuable for rough building and lime making. In five counties. Named by Branner from Izard County.

The Calciferous or Magnesian limestone beds at the Narrows, near Eureka Springs.

Saccharoidal Sandstone, (I, 119 and 120, 1890; II, 20, 1891) crumbles readily; varies in thickness to 125 feet. Named simply to designate the physical nature of the bed.

Magnesian Limestone, (I, 102, 1890; IV, 115, 1890; II, 27, 1892) covers wide areas in northern part of State. Calciferous of N. Y. (H. S. W.). Cambrain of Missouri (IV, 116, 1890).

The following formations will be recognized in the present report:

12.	*Genevieve, or Boston group*, including shales and limestones	Caboniferous.
11.	*Batesville sandstone*	
10.	*Spring creek Black shales and limestones*=Fayetteville shale of Dr. Penrose's report	
9.	*Cherty beds* — "Boone chert" of the various annual reports, of early Caribonifcrous age, ranging from Chouteau to Keokuk	
8.	*Carrollton limestone* — "Boone chert" of the various annual reports, of early Caribonifcrous age, ranging from Chouteau to Keokuk	
7.	*St Joe marble* — "Boone chert" of the various annual reports, of early Caribonifcrous age, ranging from Chouteau to Keokuk	
6a.	*Eureka shale* (typical)	
6.	*Sylamore sandstone*; *Eureka shale* (in part), and green shales underlying the Sylamore sandstones, all of which may be grouped together as Devonian interval formations	Devonian.
5.	*St. Clair limestone*, of Niagara age	Silurian.
4.	*Polk Bayou limestone*, of Cincinnati age	Ordovician
3.	*Izard limestone*, probably of Cincinnati age	
2.	*Saccharoidal sandstones*	
1.	*Calciferous*, or Magnesian *limestones*	

ORDOVICIAN.

The Ordovician faunas are recognized in (1) the Magnesian limestones, and (4) the Polk Bayou limestones. The age of the other two formations, viz., (2) Saccharoidal sandstone and (3) Izard limestone, is determined on stratigraphic position alone.

1. *Fauna of the Calciferous or Magnesian Limestone.*

A few imperfect specimens have been obtained from the various outcrops of this terrane; the best, but those very poor, are from the Narrows, on the White River, north of Eureka Springs. (Locality 1409, U. S. National Museum.) The forms recognized may be referred to Vanuxem's species:

1. *Ophileta complanata* Van.

2. *Ophileta levata* Van., and traces of a few other forms; sufficient to mark the horizon, but not perfect

enough for biological classification. These species were originally described from the Calciferous formation of New York.

3. *Raphistoma* ? n. sp. From the Narrows on White River near Eureka Springs; also from the Bean mines on the North Fork of White River in Baxter County.

4. *Machurea* sp ? "From the zinc region of North Arkansas." Precise locality not known.

5. *Ethmophyllum* ? n. sp., or cf. E. profundum Bill. Black Rock, Lawrence County, quarry half mile below railway bridge.

6. *Ethmophyllum* n. sp., or Archaeocyathus.

7. *Orthis cf. O. tricenaria.* Black Rock, Lawrence County, quarry half mile below the railway bridge.

2. *Saccharoidal sandstone and Izard limestone.*

No trace of fossils has been seen in the Saccharoidal sandstones or in the Izard limestones; but from their position they are identified as probably lower than the Trenton, or the latter may represent the base of the Trenton limestone.

4. *Polk Bayou limestone.*

Localities: The localities from which specimens containing the fauna of this limestone were obtained are as follows: (The numbers indicate the station numbers for the collections of the U. S. Geological Survey ultimately to be deposited in the National Museum.)

1235A—Two miles above Batesville, Independence County, in valley of Polk Bayou.

1235B—A section 1-4 mile up the creek from station 1235A, near a manganese mine.

1281A—Roasting-ear Creek, in north-western part of Stone County, 8 miles south-east of Big Flat.

1278A—Rush Creek, Marion County, section along the creek.

1238A—St. Joe, Searcy County, section along the creek from mining camp to the town.

The collections from all of these localities give evidence of a common geological horizon.

Fauna of Polk Bayou Limestone, on Polk Bayou, Independence County, Ark. (1235A.)

1. *Orthis* (*Plectorthis*) *plicatella* Hall.
2. *Orthis* (*Plectorthis*) *fissicosta* Hall. (?)
3. *Orthis* (*Dalmanella*) *testudinaria* (Dalman).
4. *Platystrophia biforata* (Schlotheim).
5. *Plectambonites sericeus* (Sowerby).
6. *Rafinesquina alternata* (Emmons).
7. *Rafinesquina alternistriata* Hall.
8. *Rafinesquina camerata* (Conrad).
9. *Rafinesquina deltoidea* (Conrad).
10. *Strophomena nutans* (Meek).
11. *Rhynchotrema capax* (Conrad).
12. *Zygospira* (?) sp. (?)
13. *Cleidophorus* sp. (?)
14. *Avicula* sp. (?)
15. *Asaphus gigas* Dekay (?). (Small specimen)
16. *Ceraurus pleaurexanthemus* Green. (?)
17. Trilobite (gen. and sp. undet.)
18. Crinoid stem.

Fauna of Polk Bayou Limestone on Roasting-ear Creek, Stone County, Ark. (1281A.)

1. *Monticulipora lycoperdon* (Say).
2. Cf. *Dinobulus sp.* (?)
3. *Orthis* (*Hebertella*) *occidentalis* Hall, var.
4. *Orthis* (*Dalmanella*) *testudinaria* (Dalman).
5. *Orthis sp.* (?)

6. *Rafinesquina alternata* (Emmons).
7. *Strophomena nutans* (Meek).
8. *Rhynchotrema capax* (Conrad).
9. *Orthocerus* sp. (?)
10. *Orthocerus* sp. (?)
11. *Endoceras* sp. (?)
12. *Endoceras* sp. (?)

The close affinity of this Polk Bayou fauna to that of the Cincinnati group of Ohio is evident at a glance. Such species as *Plectorthis fissicosta, Strophomena nutans* and *Rhynchotrema capax* are not reported from the New York sections, but are common Cincinnati species; the latter named species is abundant at several places in Arkansas. In none of the specimens of rock containing any of these species were there any typical Silurian forms. Some of the genera are the same, but the genera, commonly regarded as beginning with the Silurian, are not present in this fauna.

At Cane Spring, 18 N., 14 W., sections 13 and 24, fossil Ostracoda, were found in loose blocks along the slopes of the hills near the mines. Some of these were sent to Professor E. O. Ulrich, who kindly examined them, and writes as follows:

NEWPORT, KY., Nov. 13, 1900.

PROF. J. C. BRANNER, Stanford University, Cal.

Dear Sir—I have just finished a careful examination of the ostracod received from you. As I feared, it turns out to be an undescribed species and therefore throws no positive light on the age of the strata from which it was derived. * * * * * It belongs to my genus *Leperditella,* of which over 25 species are at present known. Since all of them belong to the Ordovician system and most of them to early Trenton rocks, it is fair to assume, in the absence of contrary evidence, that your species also is Ordovician.

Among the Ostracoda I notice a few minute Gastropoda, apparently of the genus *Cyclora,* and a cast of a small pelecypod, reminding greatly of species of *Lyrodesma.* The latter genus is known so far only in rocks of the Trenton and Cincinnati periods. Excepting its remarkable recurrence in the Devonian phosphate bed of Tennessee, the same is true of *Cyclora.*

Regretting my inability to determine these fossils more exactly, I remain, Sincerely yours,

E. O. ULRICH.

THE NAMES OF THE TWO LIMESTONES ASSOCIATED WITH THE MANGANESE DEPOSITS OF ARKANSAS.

In the Annual Report of the Geological Survey of Arkansas for 1890, Vol. I,* Dr. Penrose refers to the limestone in which the mangenese deposits of the Batesville region occur, under the name of St. Clair limestone. It is described in the following words:

"Immediately overlying this (the Izard limestone) is a bed of highly crystalline limestone, reaching a maximum thickness of over 150 feet, and designated as the St. Clair limestone. This formation is the source of the manganese ores in the Batesville region, as will be more fully explained in chapter VIII, and is extensively developed throughout the manganese area. It contains a fauna which has been determined by Dr. Williams, as belonging in some places, to the upper part of the Lower Silurian age, corresponding to the Trenton Limestone of the New York section, and in others to an epoch intermediate between the Trenton and Niagara. Fossils collected on Polk Bayou, four miles north of Batesville, have been determined by him as undoubted Trenton forms; while fos-

* Manganese; its uses, ores and deposits, by R. A. F. Penrose, vol. I, 1890, pp. 1-642, Little Rock.

sils from St. Clair Springs, eight miles northeast of Batesville, and from elsewhere in the country to the west, are considered by him to be intermediate between those of the Trenton and Niagara. The bed appears to be continuous, and Dr. Williams places it, chronologically, in the latter intermediate position." (p. 114.)

This explains the view I took of the problem on the evidence in hand before personally going into the region. The last sentence expresses the position I was obliged to take on the assumption that the limestones were continuous, as those who had been in the field claimed them to be. After going into the Batesville region and seeing the rocks, I was confirmed in the view that there were two distinct limestones concerned, with the manganese beds between, as was reported in the American Journal of Science in 1894.* In that paper I applied names according to the usage which had been adopted in the Arkansas Reports, so far as I could use them correctly, which led to restricting the name St. Clair limestone to the lower member which is of Trenton age. I proposed a new name, Cason limestone, for the upper member of Niagara age; and called the Manganese bearing shale which lies between, Cason shale.

Mr. Gilbert Van Ingen, in a private letter dated August 5, 1896, after having examined the various outcrops of the limestones in dispute, called my attention to the impropriety of adopting these names; stating that the Cincinnati member of the series does not appear in the region of St. Clair Springs, and that the name St. Clair should be applied to the Niagara member. This agrees with the opinion I had of the formations based upon a study of the fossils sent in; and in all my correspondence regarding the paleontology of the district with Dr. Branner, I had used the name Polk Bayou limestone for the Cincinnati

* On the age of the Manganese beds of the Batesville region of Arkansas, A. J. S., XLVIII, p. 325-331.

member, following a table of formation names sent by Dr. Branner, in a letter dated August 14, 1889.

In the course of study of the fossils, the specimens from St. Clair Spring were found to be typically representative of a higher fauna, and in my notes these were labeled St. Clair limestone. Since the field geologists insisted that there was but one limestone, they adopted the name St. Clair for the whole, and my misuse of the name, in restricting it to the lower member, arose from a desire to retain the name used in Dr. Penrose's report for that member which is most frequently associated with the manganese. I believe, however, that the facts require an application of the names according to the actual geographical distribution of the formations, and the changes involved will be as follows:

Penrose, 1891	Williams, 1894	Proper Usage	Age
St. Clair limestone	Cason limestone	St. Clair limestone, Branner	Niagara
	Cason shale	Cason shale, Williams	? Clinton
	St. Clair limestone	Polk Bayou limestone, Branner	Cincinnati
Izard limestone	Izard limestone	Izard limestone, Branner	Ordovician

The diagram (p. 284) expresses the true relations of the beds, and the nomenclature which is in accordance with the facts now in sight. This diagram should take the place of the one published in 1894.*

In the present report the name Polk Bayou limestone is used for the Ordovician, and St. Clair limestone for the Silurian, member of this series, in accordance with this adjustment. As has been shown on a previous page, the fauna of the Polk Bayou limestone is more closely related to the Cincinnati group than to that of the Trenton of New York. In previous discussions of the fauna of this Ordovician limestone the name Trenton was used in the sense "Trenton Period" of Dana's Manual, which includes the Trenton, Utica and Hudson Epochs. According to that

* On the age of the Manganese beds, etc., Am. Jour. Sci., Oct., 1894, XLVIII, p. 327.

classification the Polk Bayou limestone of Arkansas would belong to the Hudson Epoch. Faunally, however, the combination of species is that of the Cincinnati group, which name I have substituted in this report for Trenton of the previous papers on the subject.

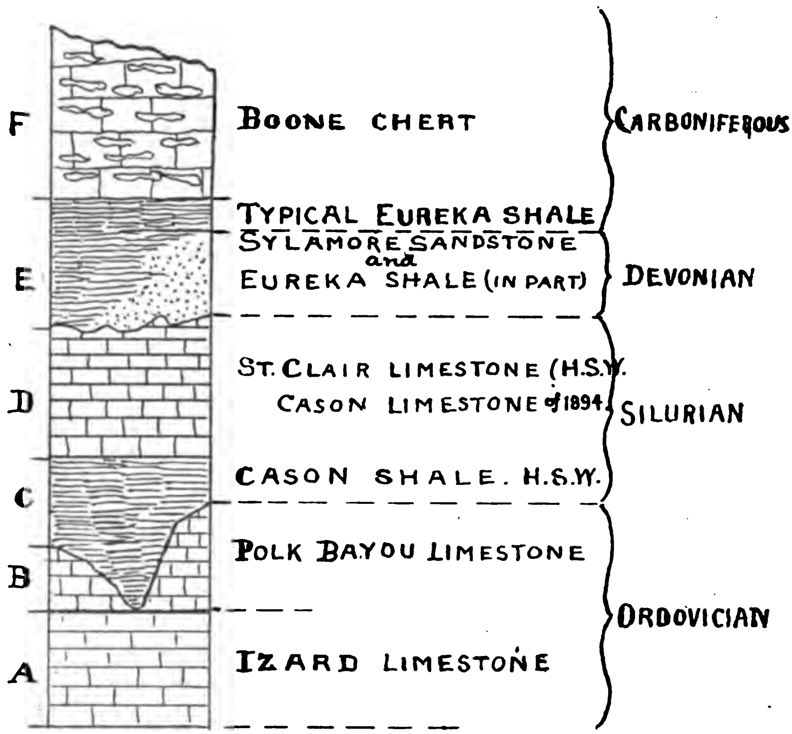

Fig. 92. Classification of the geologic formation of North Arkansas up to the Boone chert.

The Silurian Formations.

The Arkansas formations which contain Silurian faunas are the St. Clair limestone (H. S. W.) and the Cason shale (H. S. W.).

The St. Clair limestone of the Arkansas reports includes the Polk Bayou limestone of this report which has already been shown to contain an Ordovician fauna.

In the present chapter the faunas of the St. Clair limestone, and the relations, both paleontological and stratigraphical, of the St. Clair limestone to the Polk Bayou limestone, will be discussed in detail.

The St. Clair limestone.

The typical St. Clair limestone is from the outcrops above St. Clair Spring, north of Batesville, in Independence County (station 1240A). None of the specimens in which the fauna is contained are so strongly reddened as the typical Polk Bayou limestone, or as the St. Joe marble which always appears above the interval in all the sections of which I have evidence. The St. Clair Spring specimens are light cream, gray, or slightly pinkish in color, and the Searcy County specimens are nearly of the same color. The study of the fauna shows it to be of Niagara age, of the Waldron, or Kentucky type, rather than as expressed in New York.

The two limestones, Polk Bayou and St. Clair, appear to be continuous across the state—occasionally one, then the other, forming the top member of the Silurian terrane; but in the manganese region the upper member is often absent. My suspicion is that the red color is connected with the Carboniferous terrane and the sediments which introduced it, and that the underlying Silurian limestones get their color as a secondary stain which is not original to that limestone.

The following list of species was prepared from a study of the materials collected by Mr. Stuart Weller, and elaborated by Mr. Gilbert Van Ingen. Most of the specimens are small, and some of them are so minute as to require the aid of a magnifying lens. They were determined by use of literature alone in most cases, without comparison with the types, so that the specific identifications may be modified when the specimens shall be more thoroughly

studied. In many of the identifications I have passed critical judgment, but the list as it stands is due to the patient work of Mr. Van Ingen.

Fauna of the St. Clair limestone at St. Clair Springs, Independence County, Arkansas. (1240A.)

1. *Duncanella borealis* Nicholson.
2. *Streptclasma calyculus* Hall.
3. *Zaphrentis bilateralis* Hall.
4. *Caryocrinus ornatus* Say(?) (Fragments.)
5. *Homocrinus parvus* Hall. (?)
6. *Stephanocrinus angulatus* Conrad.
7. Crinoid columns.
8. Crinoid calyx.
9. *Lichenalia concentrica* Hall.
10. *Stictopora sp.* (?)
11. Bryozoa (several undet. spec.)
12. *Crania* sp. (?)
13. *Dinobolus conradi* Hall (?)
14. *Orthis* (*Dalmanella*) *elegantula* (Dalman).
15. *Orthis* (*Rhipidonella*) *hybrida* (Sowerby).
16. *Orthis nisis* Hall and Whitfield.
17. *Orthis rugaeplicata* Hall and Whitfield.
18. *Orthis cf. jamesi* Hall.
19. *Streptis grayi* Davidson.
20. *Hyatella congesta* (Conrad).
21. *Triplecia ortoni* Meek.
22. *Plectambonites transversalis prolongatus* (Foerste).
23. *Plectambonites sericeus, cf. var. intermedius* (Ringueberg).
24. *Strophodonta profunda* Hall.
25. *Strophomena sulcate* DeVerneuil.
26. *Strophonella semifasciata* Hall.
27. *Leptaena rhomboidalis* Wilckens.

28. *Chonetes cornutus* (Hall).
29. *Atrypa nodostriata* Hall. (?) (young.)
30. *Atrypa*(?) *sp.*(?).
31. *Atrypina disparalis* Hall.
32. *Atrypina*(?) *sp.* (?)
33 *Meristina* (*Whitfieldella*) *nitida* Hall.
34. *Whitfieldella nitida oblata* Hall.
35. *Whitfieldella cyclindrica* Hall.
36. *Whitfieldella intermedia* (Hall).
37. *Nucleospira pisiformis* Hall.
38. *Retzia* (*Homoeospira*) *evax* Hall.
39. *Spirifer radiatus* Sowerby.
40. *Spirifer cf. rostellum* Hall and Whitfield.
41. Brachiopod. gen. and sp. undet.
42. *Bellerophon tuber* Hall.
43. *Murchisonia cf. conradi* Hall.
44. *Platyceras* (several undet. spec.).
45. *Platystoma niagarense* Hall.
46. *Pleurotomaria idia* Hall.
47. *Strophostylus cyclostomus* Hall.
48. *Strophostylus* sp.(?).
49. *Conocardium cf. ornatum* Winchell and Marcy.
50. *Conocardium* sp.(?).
51. *Orthoceras angulatum* Wahlenberg(?).
52. *Orthoceras medullare* Hall.
53. *Cornulites proprius* Hall.
54. *Acidaspis danai* Hall.
55. *Bronteus acamus* Hall. *B. occasus* Winchell and Marcy.
56. *Calymene niagarensis* Hall.
57. *Calymene* sp.(?).
58. *Ceraurus niagarensis* Hall.
59. *Dalmanites limulurus* Green.
60. *Dalmanites vigilans* Hall.
61. *Dalmanites* sp.(?).

62. *Encrinurus punctatus* Wahlenberg.
63. *Illacnus ioxus* Hall.
64. *Illaenus* (?) sp. (?).
65. *Lichas breviceps* Hall.
66. *Lichas boltoni* Hall.
67. *Lichas phlyctanodes* (Green).
68. *Spaerexochus romingeri* Hall.
69. *Beyrichia* sp. (?).

Fauna of St. Clair limestone at Providence, Searcy County, Arkansas, (1414A.)

1. *Plectambonites sericeus* (Sowerby) var.
2. *Plectambonites sericeus, var. intermedia* (Ringueberg).
3. *Leptaena rhomboidalis* Wilckens.
4. *Atrypa reticularis var. niagarensis* Nettelroth.
5. *Whitfieldella intermedia* (Hall).
6. *Nucleospira pisiformis* Hall.
7. *Spirifer radiatus* Sowerby.
8. *Murchisonia petilla* Hall and Whitfield.
9. *Platyceras* sp. (?)
10. *Strophostylus cyclostomus* Hall.
11. *Cyclonema rugaelineatum* Hall and Whitfield.
12. *Cornulites proprius* Hall.
13. *Calymene niagarensis* Hall.
14. *Illaenus ioxus* Hall.
15. Bryozoa.

An interesting member of the St. Clair limestone fauna is *Streptis grayii,* Davidson, represented by several good specimens.* This is the first discovery of this species in American, so far as has come to my knowledge, and the Arkansas specimens present not only the characters of the Bohemian and English specimens, in surface marking.

* See Am. Jour. Sci., 3d Ser., XLVIII, 1894, p. 331.

general form and the assymetry, but among the few specimens found together in the St. Clair limestones there are both right and left handed twisting, causing the right half of the valve to be elevated in some, and the left half to be elevated in other specimens. Attention is also called to *Stephanocrinus angulatus* Con. I have much doubt regarding the specimens referred to *Dinobolus Conradi* Hall. The Arkansas specimens are small, though presenting the form of that species, it is improbable that they are the same species. The Conocardium, referred to *C. ornatum* of Winchell and Marcy, is represented by several specimens so that the features of the shell are well made out. The carinated area which is marked in the Illinois species by two defined ridges in the Arkansas specimens seem to be the base of a laminated frill or fan as described by Barrande. Fischer proposes the name *Rhipidocardium* for this section of the genus. The small size of the species in this fauna, and the fact that the specimens are in cases smaller than the size attained by the same species in other localities, are important as characteristics of the fauna.

ON THE RELATIONS BETWEEN THE POLK BAYOU AND ST. CLAIR LIMESTONES.

On account of the great difficulty presented in identifying the two limestones in the field, and after I had called Dr. Branner's attention to the separate faunas, and after the publication of Dr. Penrose's report on the manganese deposits, the sections were re-examined and new specimens, with fossils whenever practicable, were collected. For this purpose, Dr. Branner commissioned his assistant, Dr. T. C. Hopkins, to examine and collect specimens from the typical manganese sections and note the exact relation each specimen held to the manganese bed in each case. Many of these specimens contained fossils. They were all

sent to me, and after a minute examination of them in connection with the described sections, the whole matter was reviewed and the paper,* before referred to, was published. The following notes will show how the two limestones may be distinguished in the different localities, and will furnish the facts upon which the conclusions given in that paper were based.

New Southern mine.—14 N., 7 W., section 1, the northwest of the southwest quarter. Penrose Manganese Report, pp. 199, 260, 265.

Specimens Nos. 1, 2, 3, 4, T. C. H.

"No. 1. First rock *in situ* below the manganese at New Southern mine."

This is a flinty limestone like samples seen of the Izard limestone, no fossils are evident. (Cf. 1278B1, 1238C2. The latter specimen 1238C2 was from below the Polk Bayou limestone.)

"No. 2. Manganese ore from New Southern mine." No fossils.

"No. 3. Rock accompanying the manganese ore in New Southern mine." A rotten-stone; no fossils.

"No. 3a. Rock accompany manganese ore." Quartz ore like No. 9.

Specimens Nos. 2, 3 and 3a, all made up of limestone debris, consolidated together by the ore and mineral deposited in the interstices; same as one of the pieces of No. 4, and so far as can be told by comparison of the material with other samples of known age, this is of Ordovician age. The staining of the chert shows that the infiltration of the solution could easily color the underlying limestone whenever porous, and that the deposit of crystalline man-

* On the age of the Manganese beds of the Batesville region of Arkansas, A. J. S., XLVIII, pp. 325-331.

ganese in lenses in cavities is to be expected. There is among these specimens no trace of the upper St. Clair limestone, the next overlying rock is of Carboniferous age.

"No. 4. Chert overlying manganese ore at New Southern mine, T. C. H." In this lot are three fragments: No. 4a is a piece of unfossiliferous chert, looks like ordinary Carboniferous chert; No. 4b is a fragment of limestone same as No. 12a; No. 4c is a conglomerate of Cincinnati fossils and fragments matted together by infiltrated and deposited mineral matter, as in No. 3a. These decide nothing as they disagree.

Old Southern mine.—

Specimens Nos. 5 and 8, of T. C. H.

"No. 5. St. Clair marble from Old Southern mine, T. C. H."

This is a coarse crystalline limestone, no fossils and, appears to be same as No. 30, from Cason mine, and is probably of Ordovician age.

"No. 6. Rock accompanying ore at Old Southern mine, T. C. H."

Iron stained rounded agglomerate of coarse sand, no fossils. Nothing in these specimens to determine certainly the age, but indications all in favor of Ordovician rather than Silurian age.

Meeker's Place.—14 N., 7 W., section 8, Penrose Manganese Report, p. 127.

Specimens Nos. 7, 8, and 9, T. C. H.

"No. 7. St. Clair limestone from Meeker's Place, T. C. H." Place." Purple (stained) fossiliferous limestone. Fossils of Ordovician age.

"No. 8. Managenese ore from Meeker's Place, T. C. H."

"No. 9. Rock accompanying manganese ore from Meeker's Place, T. C. H."

The limestone here is of Ordovician age; it is separated from the Carboniferous above only by residual clays, no limestone of Niagara age is seen in this section. It resembles that at the Southern mine, and is therefore Polk Bayou limestone, not St. Clair as named by Hopkins.

O'Flynn's Mine.—14 N., 6 W., section 22, the southwest of the northeast quarter, Penrose Manganese Report, pp. 230-231.

Specimens Nos. 12, 14, 16, 20, T. C. H.

"No. 12. O'Flynn's mine, 14 N., 6 W., section 22; all the fossils are from the Rhynchonella bed at O'Flynn's, T. C. H." Fossils. All Ordovician types (*Rhyncholrema capax*).

"No. 12a. Fifteen feet above the Izard Limestone and about 60 feet below the manganese ore at O'Flynn's mine, T. C. H."

The fossils are imperfect, but suggest *Leptaena plicifera* Hall, and "*Atrypa*" *altilis* Hall, of vol. I, Pal. N. Y.; and, if so, would be of Chazy age, but more and better specimens will be necessary for certan determination. The specimens are unsatisfactory, but do not contradict other evidence.

"No. 12b. From bottom of manganese shaft of O'Flynn's mine, T. C. H." The fossils in this limestone are not distinctive, probably of the Ordovician age.

"No. 14. O'Flynn's mine; limestone just below the chert about 50 feet above the manganese, 14 N., 6 W., section 22, T. C. H."

A fossiliferous limestone, but the fossils in the specimen are fragmentary and indistinct; the rock

is purplish, showing the manganese stain and differs from No. 16. The fossils suggest *Orthis jamesi,* and a species of *Duncanella,* and are probably of Ordovician age, as Nos. 16 and 20, and from Polk Bayou limestone.

"No. 15. Samples from rock containing the manganese at the same level as the 'Rhynchonella beds,' about 50 feet below top of limestone and 75 feet above bottom of limestone. A. G. S., T. C. H."

This sample shows the rounded siliceous grains and concretions and filling of mineral matter, nodules and black and brown color, so characteristic of the interval fillings throughout this region, but no fossils appear to determine whether the age be the Silurian or Devonian. The material is evidently residual and derived from decay of rocks, not those immediately surrounding it.

"No. 16. O'Flynn's mine, 300 yards east of the mine; pockets of manganese ore in the limestone; the surface covered with chert debris. T. C. H."

The fossils in these specimens are distinctly Ordovician in age, as *Orthis alternistriata* and *monticulipora lycoperdon.* In the specimen marked "O'Flynn's mine, 10 feet above the manganese," the fossils are the same besides those above, a form closely resembling if not identical with *Strophomena* (Raphinisquina) *deltoidea.*

This material is also evidently residual and as no trace of the upper Silurian fauna is discovered in the rock the interpretation is that the pockets of ore are on the surface of an uneven Ordovician limestone and represent the interval between the two limestones, when the upper one is present.

"No. 20. O'Flynn's mine, hill opposite (south), 20-30 feet as fossiliferous as this."

All the fossils in this specimen are of the Polk Bayou fauna. *Orthis testudinaria* is abundant. The sample is fine-grained and of grey-purple color.

At this O'Flynn mine there appears no trace of the Niagara fauna, the Carboniferous chert seems to lie next above the manganese deposits.

Cave Creek.—14 N., 6 W., Penrose Manganese Report, p. 229.

Specimen No. 26.

"No. 26. Cave Creek, near mouth."

This is a specimen containing a single discernible fossil. *Rhynchonella capax* Con., which marks the Polk Bayou fauna.

Mr. Penrose describes the relation of the ore to the limestone on page 229 of his report, indicating that the ore is in the upper part of the creek and the limestone in the lower with little clay. I interpret this as evidence that the erosion forming the cavities in which the residual material is contained was prior to the erosion expressed by the present topography of the surface, and hence that the "caves" were made between the two limestones. The rock on which the residual ore rests should, according to this interpretation, always rest on rock older than the Silurian rock containing the Niagara fauna, which all the fossil evidence confirms.

Trent mine.—14 N., 6 W., section 10, the northwest and northeast of the southeast quarter, Penrose Manganese Report, p. 242.

Specimens Nos. 18, 21.

"No. 18. Trent mine, St. Clair limestone containing manganese, T. C. H."

A fossiliferous limestone, deep purple but fine-grained, and fossils in fragments, too indistinct to make out species but indications are all toward the Cincinnati rather than the Niagara faunas, and appear to be the same as Nos. 16 and 18a.

"No. 18a. Trent mine, fossiliferous limestone containing manganese ore in irregular nodules and layers, T. C. H., March 11, 1893."

This is a deep purple limestone, fossils all of Cincinnati age. The manganese appears to be infiltrated into the limestone, as the stain is upon the grains of calcite and upon the fossils, and not a part of their intrinsic color, the purplish material appears in druses and as coating upon fossils and sides of crack faces (quite the same as 25).

"No. 21. T. C. H. upper Cave Creek near Trent mine."

This is a purplish limestone; the material itself being light pink to cream color. The fossils *Illaenu ioxus, Spirifer radiatus,* with variations off toward the sp. niagarensis form, mark the fauna as of Niagara, or early Silurian age.

"No. 21a. Residual ore-bearing clay from Trent mine, T. C. H."

No fossils and no evidence to show its age except its relation to surrounding rocks.

All the limestone which is marked as from the Trent mine, and shows any indication of manganese ore, or stain, is clearly of Cincinnati age. The specimen marked No. 21, from Cave creek, near the mine, is of Niagara age, but shows no trace of manganese. The manganese is described as "in clay in hollows or caves running down to unknown depths" (see Manganese Report, p. 233). If we suppose the manganese deposits to be residual products washed into cavities or hollows in the surface of the Cin-

cinnati rock before the Niagara limestone was deposited, we have a rational explanation of the phenomena. It is to be observed that we have reason to expect such an erosion and elevation at the time indicated, since a little further east the Cincinnati anticlinal arch reached the surface during this interval, and the disurbance further east, marked by the crumpling of the Taconic region east of the Hudson river, is shown to have taken place at this general period of geological time.

Cason Place.—14 N., 6 W., section 34, Penrose Manganese Report, p. 219.

Specimens Nos. 22, 27, 28, 29, 30, 31, 32.

"No. 22. Cason place, limestone 120 feet above manganese, T. C. H."

This is the light cream-colored limestone, with *Spirifer radiatus, Illaenus ioxus, Dalmanites limulurus,* etc., indicating the Niagara fauna without any doubt.

"No. 27. Cason mine, Boone chert immediately overlying the limestone, T. C. H."

This chert contains no fossils, but in appearance it resembles the residual product from decay of the Carboniferous chert-bearing limestone of the region.

"No. 28. Cason mine, immediately overlying the manganese deposit, T. C. H."

This is the light cream-colored limestone showing some trace of the superficial purplish stain characteristic of manganese; its fossils are distinctly of the Niagara fauna (*Illaenus ioxus* and *Dalmanites*).

"No. 29. Cason mine, 100 feet above the manganese, T. C. H."

A fine-grained grayish limestone containing large fragments of *Illaenus*, belonging to the Niagara fauna.

"No. 30. *Cason mine*—from bottom of shaft, T. C. H."

The specimen, in physical appearance, resembles the samples from other localities of Cincinnati age; it presents no fossils, the crevices are filled with shaly greenish matter, age not certain.

"No. 31. Cason mine, same level as manganese, T. C. H."

This specimen is distinctly of the same limestone as those from above (22 and 27). The fossils distinguishable are *Leptaena rhomboidalis*, and a fragment of *Illaenus*. There can be no doubt of the Niagara age. As it is described as from the same level as the manganese it is very important, as the first specimen met with of Niagara age which is not reported as distinctly above the manganese deposits. I examined it with the greatest care, and discovered the whole surface of the specimen shows evidence of having been exposed to the weather for a year or two at least, there is not a single place on the specimen which shows a fresh fracture. I conclude, therefore, that it was a loose specimen picked up by Mr. Hopkins on the surface, and that its unexpected relation to the manganese is due to the fact that it belongs to the limestone above, and has fallen down to the position in which it was found.

The Cason place mine is the most southern one of those described. Dr. Penrose describes the ore-bearing stratum as running under the limestone on the western side, which rises above it for a hundred feet or so (p. 220). According to the fossils, all the limestone above the manganese is of Niagara age.

Here, too, the ore is described as stratified, and it is here that the "button-ore deposits" occur (p.

221). This description agrees with the supposition that the original manganese ore was a regular deposit on the surface of the eroded Polk Bayou limestone, and that its original condition is preserved where the cap of St. Clair limestone has not been for some time removed.

The clayey condition of the deposits in other regions would result from the disintegration of the sediment when exposed to the elements of atmosphere and infiltrating waters. From this section, too, I draw the conclusion that the manganese bearing sediment was accumulated immediately previous to the laying down of the following limestone of Niagara age, and thus was incident to the sinking of the land surface from along whose shores the materials for the sediment were derived. The next specimen bears out this theory with still greater force.

"No. 32. Rocks at same level as manganese bed at the Cason mine, T. C. H."

This specimen appears to have on it the stain which is associated with the weathering of the manganese ore upon the rocks exposed to its wash; it has the concretionary-like buttons or pellets. At first no traces of fossils were discovered in this mass, but the fact that everything pointed to this being actually the upper layer of, or the layer following, the actual manganese bed in its original position, led me to break up the material and examine it with microscopic care. The search revealed two interesting forms which I identified with *Leptaena sericea var. intermedia,* Ring. (Am. Nat., Sept., 1882, p. 714), *Atrypa disparilis,* Hall, Pal. N. Y., p. 277, Pl. 37, Fig. 6. The Leptæna seen in the limestone above is the form described now under the

name *Plectambonites transversalis var. elegantula* Hall (see Foerste's Fig. 6, Pl. 17, ? B. S. N. H., XXIV). If we had only this we might consider it as a modified form of the Trenton horizon; and I have shown in another place,* that the peculiarity of this specimen does seem to be found in McCoy's *Leptaena quinquecostata* of the Bala and Caradoc. And I have no doubt that this is the ancestral origin of the form, but that the fauna is of later age than the Trenton, the associated *Atrypina* (*Coelospira*) *disparilis* is proof, which is of distinct Silurian, and not Ordovician age whenever found in diagnostic associations.

This specimen (No. 32) thus may be interpreted as of Clinton or Niagara age, and as the true age of the rocks from which the manganese ores of Arkansas were deposited. That this is the horizon of iron ore, accumulations in other parts of the interior continental basin is not surprising. These shales at the Cason mine, containing the manganese ore and described by Penrose as "slaty or sandy layers interbedded in the limestone",† is the formation to which I gave the name *Cason shale,* in the paper on the age of the manganese beds above referred to. The names opposite the woodcut in that paper (p. 327) are in wrong order, but on p. 329 the order is rightly given in text; i. e. Cason limestone, Cason shale, St. Clair limestone, as described on a previous page of the present report (p. 285).

* Age of the Manganese beds of Arkansas, A. G. S., XLVIII (1894), pp. 330, 331.

† Manganese; its uses, ores, and deposits, by R. A. F. Penrose, vol. I, Ann. Rep., Arkansas Geol. Survey for 1890, p. 219.

Polk Bayou.—See Penrose Manganese Report, pp. 216-223.

Specimens Nos. 23, 24, 25.

"No. 23. From the Siluro-Carboniferous interval Polk Bayou, T. C. H., March 13, 1893."

"No. 24. Polk Bayou, above the interval, bottom of chert, T. C. H."

These two specimens seem to be residual clay containing no fossils, and are probably the residual matters from decay of the limestone, which may have been Carboniferous in age.

"No. 25. St. Clair limestone of Polk Bayou, T. C. H."

This is the fossiliferous purple limestone, with *Orthis testudinaria* in abundance, underlying the manganese bed, and receiving its purple color, as I conceive, from the infiltrated wash from the weathered or decomposing manganese deposits always occurring above it in this region. (Similar to No. 18a.)

The following specimens do not throw any light on the problem immediately under investigation.

"No. 10. Rock overlying the manganese ore in some places occurring in loose boulders with the ore, T. C. H."

This is a fine-grained sandstone iron stained, the grains much worn, non-calcareous, no fossils.

"No. 11. Chert immediately overlying No. 19, T. C. H."

A fine-grained sandstone with veins of opalescent chert, no fossils.

THE AGE OF THE ST. CLAIR LIMESTONE.

The above lists contain so many species which have not been seen outside the Clinton and Niagara formations, that little doubt can be entertained of the Silurian age of

this limestone. No species, in any of the rock specimens, are doubtful in their testimony. Such species as *Stephanocrinus angulatus, Streptis grayi, Atrypina disparilis, Spirifer radiatus,* are sufficient of themselves to establish the age. In addition to this specific testimony the genera are as clear; Chronetes, Atrypina, Whitfieldella, Meristella, Nucleospira, Spirifer, Retzia, Homœospira, Stephanocrinus and Caryocrinus, are characteristic Silurian genera. *Illaenus ioxus, Lichas,* all the species, *Sphaerexochus romengeri,* are sufficiently diagnostic among the Trilobites. The genera Acidaspis, Calymene, Ceraurus, Dalmanites, Orthis (cf. jamesi), Plectambonites, range from the Ordovician upward, but the specific forms which occur in this limestone are sufficiently distinctive to leave no doubt of an age later than Trenton or Cincinnati. Thus, the cumulative generic, specific and faunal evidences certify the distinctness of age for the two limestone, and no one acquainted with the nature of evidence furnished by fossils can admit that these limestones constitute a continuous formation.

The manganese deposit separates the two limestones, whenever the two are present in the same section; and whenever the manganese is present, it is always above or at the top of the Polk Bayou limestone of the section. The evidence is conclusive, therefore, that the erosion, causing the interval, was after the deposit of the Polk Bayou limestone, and the evidence of the few fossils in the Cason shale indicates that the manganese-containing deposit was made at an age closely corresponding to the Clinton of the New York sections, and was incident to the deepening seas which soon after received the limestone formation of the St. Clair (Niagara) epoch.

6. *The Devonian interval, including the sylamore sandstone, and the Eureka shale in part.*

In numerous places in North Arkansas the evidences of an unconformity separating the Silurian from the overlying Carboniferous, are very clear. In some cases there is no rock-material separating these two grand terranes. In other cases there are greenish shales, or coarse sandstones, with polished grains and rounded nodules of black shale; and in the western sections the interval is occupied, in part, by a black shale, the Eureka shale of the Washington County report.*

The materials discussed in this report are from the following localities: (The numbers before the names are the locality numbers of the United States Geological Survey under which the materials studied are catalogued preparatory to final deposit in the National Museum.)

1246. Buck Horn, Stone County, Arkansas.
1281. Roasting-ear Creek, Stone County.
1278. Rush Creek, Marion County.
1282. Dodd City, Marion County.
1414. Long Creek, Searcy County.
1238. St. Joe, Searcy County.
1277. Cave Creek, Newton County.
1410. Eureka Springs, Carroll County.
1279. War Eagle Creek, Washington County.
1291. Buffalo Fork, Newton County.

The sandstone when present is called the Sylamore sandstone in the various reports.

On passing westward from Batesville, the first locality, from which specimens representing this interval have come, is 3 miles north of Buck Horn, Stone County (No. 1246A) on Cagen Creek.

* Ann. Rep., Ark. Geol. Survey, 1888, vol. IV, p. 26.

No. 1246. Buck Horn, Stone County.

This station was first reported by Dr. Branner as "Section 3, 14 N., 9 West, at John Greenway's; over 4 feet black shale overlaid by one foot that weathers red." It is 82-11 of Hopkin's report of 1889, Oct. 3d; and was reported by me in letters Nov. 9, 1889, as "a black shale very similar to the Berea of Ohio." Afterwards, Mr. Stuart Weller was sent into the region and reported the exact sections from Cagen Creek, 3 miles north of Buck Horn, July 13, 1891.

Study of the fossils in connection with the sections resulted in the following interpretation, viz.:

1246 A1. A red marble=St. Joe marble. (Eocarboniferous.)

A2. Black shale with lingulas, several feet thick. (=Eureka shale.)

A3. A pink marble with no fossils seen, probably the Polk Bayou limestone. (=Trenton.)

This section is in the hollow on the south side of the creek. The section B was made 200 yards east of A; and B1=A1; B2=A2, but B2 is a hard, greenish black rock with rounded black pebbles; B3=A3. The 3d section is taken at a point about half a mile up the creek on the east side. C1, 2 and 3 correspond to A1; and consist first of black shales, with a band of hard black limestone 4 inches thick (C2) in the midst. This is followed above by the St. Joe marble (C4) and is capped by Boone chert (C5).

At the Buck Horn locality the interval, between the pink Silurian limestone which contains no fossils and the overlying red Carboniferous marble, contains a few feet of typical black shale, such as represents the Devonian interval in Tennessee. It contains a small Lingula which may be called *L. spatulata*, until someone succeeds in determining where to draw the specific limit between the minute

forms of the Genesee shale of New York and the several forms which succeed it in the black shale strata of the Waverly of Ohio and elsewhere.

Associated with the Lingula are Conodonts, as in the Genesee and similar shales in New York state. Two hundred yards east of this section (at 1246B) the same interval is occupied by a hard, siliceous, greenish-black rock with very hard, rounded, black nodules, with no fossils seen. In both of these interval-filling rocks are found the coarse, polished, siliceous grains so characteristic of the Sylamore sandstone, indicating identity of origin for the three kinds of material. The black shale may be called the *Eureka shale,* stratigraphically speaking; but its identity paleontologically has not heretofore been established.

(The next place from which evidence has been seen is Roasting-ear Creek, 8 miles southeast of Big Flat, in the western part of Stone County.

No. 1281. Roasting-ear Creek, Stone County.

> The materials examined from this section were collected by Weller, from a point 8 miles southeast of Big Flat, July 10, 1892. The fossils in the red limestone (A1) were supposed by him to have fallen down. They are all Trenton fossils, showing the rock to be the Polk Bayou limestone. The shale (A2) contains the same kind of black pebbles seen in 1246B2.

Here the interval-filling material is a green siliceous shale, more or less calcareous, containing fragments of shells and of what appears to be broken fish teeth, and well-rounded pebbles or nodules of hardened black shale; everything too much broken and polished to indicate the genus or even class of organisms with certainty. This rests immediately upon red marble of Trenton age, the Polk Bayou limestone. The overlying rock is not reported.

About 25 miles northwest of this section is seen another outcrop at the "narrows," 3 miles from the mouth of Rush Creek, in Marion County."

No. 1278. Rush Creek, Marion County.

The section 1278 was taken along the creek, opposite the mines, by Weller, July 9, 1891. The limestone (A2) coarse-grained, pinkish, containing Trenton fossils, is thus shown to be the *Polk Bayou limestone.* The limestone below (A1 and B1) is probably the same as the heavy bedded blue limestone, and, though no fossils are seen in it, the probability is that it is the *Izard limestone* of the reports. The coarse saccharoidal sandstone (A3 and B2) is the *Sylamore sandstone.* The red marble (A4 and B3) contains a few fossils of Carboniferous age, and is therefore the *St. Joe marble* of the reports. Section 1278B is taken on the hill, three miles from the mouth of Rush Creek. The evidence that the Sylamore sandstone represents the Black shale (Eureka shale) is clear upon comparing the sections 1278 and 1246.

Another section was seen at Dodd City.

No. 1282. Dodd City, Marion County.

The section reported was taken at a point 3 miles north of Dodd City, Durst's spring, by Weller, July 23, 1891. He reported that the red marble (A3, *St. Joe marble*) rests directly upon the blue-gray limestone (A2) which contains fossils showing it to be the *Polk Bayou* (Trenton) limestone. Below it is a bed of the Ordovician, *Saccharoidal sandstone.* No rock was discovered in the interval, but the gap was seen separating the two limestones, and as the upper one is identical

(so far as the characters of the limestone, without actually seeing fossils, can be depended upon) with the St. Joe marble of the other sections. We see here a case of a true interval, representing all the time from the Trenton to the Carboniferous, certainly later than the Chouteau, and without sufficient disturbance of the horizontality of the rocks to make the unconformity apparent.

A few miles west of the Roasting-ear Creek section, on Long Creek, near a place called Providence, Searcy County, (1414A) is seen another section, with the Silurian terrane terminated by *St. Clair limestone*, and then about two feet of interval, filled with characteristic *Sylamore sandstone,* with its polished siliceous grains, and black rounded nodules.

No. 1414. Long Creek, Searcy County.

This section, taken along the bank of the Creek, was visited by Dr. Branner and myself; and when it was first seen, it was quite impossible to imagine that the two limestones were not actually continuous. The beds lie nearly horizontal, and a stretch of their exposed edges is in sight for several hundred feet. The interval (A2) was discovered only after search. The fossils in the limestone (A1) belong to the Niagara fauna of the *St. Clair limestone*. The *Sylamore sandstone* (A2) wears away faster than the limestone and shows a retreat in the ledge of exposed rocks. When examined, it is found to be the typical Sylamore sandstone composed of polished sand grains, and pebbles of black shale and fish-bone fragments. Immediately above it comes, without ap-

parent change in the plane of bedding, the *St. Joe marble* (A3) containing Carboniferous fossils.

Still further west is the St. Joe section.

No. 1238. St. Joe, Searcy County.

In this section, the green shale, associated with the Sylamore sandstone (A4 and 5) contains nodules like those in the sandstone; and the Lingulas in the black nodules, point to a common origin for the varying kinds of deposit, i. e., black shale, Sylamore sandstone, and this green shale containing the black nodules. A piece of large fish-plate indicates the age to be as late as Devonian, but, in itself, does not make certain that it may not have been late Devonian, though the probability is that it belongs below the latest Devonian. At this point the termination of the Silurian terrane (A2) is Trenton limestone (Polk Bayou limestone). The interval material is, first, a few feet of green, gritty mud shaly rock (A4), including a few black, rounded, hard nodules, its upper part shaly, followed by four inches of Sylamore sandstone (A5), with its characteristic polished siliceous grains and black worn nodules. The nodules are slightly calcareous, due either to infiltration of calcite, or included fragments of shell. Some of the nodules contain pieces, and whole shells of Lingulas, but the structure of the nodules suggests agglutination. In one of them a grain of the polished silica is enclosed; and in another the nodule is made up of fragments of shells and oölitic grains. The sandstone is followed above by a compact, red Carboniferous limestone (A6) of 30 feet thickness. The under surface of this limestone, where it came in contact

with the interval sandstone, is penetrated, or contains black nodules like those below, two specimens were obtained partially surrounded by the crystalline limestone. The Lingula is like a minute *Lingula spatulata* of the New York black shales, but is rather shorter and more solidly formed than the ordinary type of *L. spatulata.* However, the variability expressed in the few specimens examined leaves no mark for differentiating it specifically from *L. spatulata,* as seen in sundry localities in the north.

In one piece of the Sylamore sandstone, a large fragment of a fish-plate was found, reminding one of the plates of Dinichthys of the Black shales of Ohio. But the piece is worn and crushed, and its original outlines are indistinguishable. The bony texture is preserved, and the fragment, 2 by 3 inches in diameter, is 1-4 to 1-2 inch in thickness.

In Newton County, a section was seen near the Saltpetre Cave, Cave Creek P. O.

No. 1277. Cave Creek, Newton County.

The first specimens seen from this section were collected byMr. Hopkins in the summer of 1890, and were marked as from Saltpetre Cave at Cave Creek P. O. In the next season Mr. Weller collected from the same section, sending in enough specimens to make out the several elements of the section. The interval-material of this section is a hard, black, shaly rock, about 18 inches thick (A2) separating the Polk Bayou limestone (A1) from the overlying red marble (A3), the St. Joe marble, which is here 10 feet thick; above it lies the cherty limestone (A4) which is called Boone chert in the Reports. The

The black shale (A2) contains Lingulas as in the St. Joe section.

The typical locality for the black shale is Eureka Springs, from which the formation derives its name.

No. 1410. Eureka Springs, Carroll County.

The full section of the rocks at Eureka Springs is given in Volume IV of the Annual Reports of the Arkansas Geological Survey for 1890.* The part of it interesting in this place is that given in my section 1410A. A1 is the top of the saccharoidal sandstone; resting immediately upon this and without any apparent change in the plane of bedding is the black shale (A2). In the section, in the midst of the city, the thickness of black shale is about 4 feet, with a foot above it of green shale. In some places the green shale is several feet thick. When I visited the locality, an excavation for the cellar of a building exposed a fresh cut of about 6 feet of the greenish shale, from which a few fossils were obtained. The black shale ran up into the green without any sharp line of sudden change showing a continuous deposition. The part is, however, the typical Eureka shale (A2), while the upper green part is a representative of the formation which in Tennessee is much more important and constitutes in that region the lower member of the Carboniferous system. The sandstone (A1) below the Eureka shale is the Ordovician rock lying below the Polk Bayou limestone. It will be noticed that where the black shale, filling the interval, is present and thickest in the northwest it rests on the

* Marbles and other limestones, by T. C. Hopkins, 1893.

lower formations, below the Polk Bayou limestone, and the erosion has cut into the saccharoidal sandstones. It seems probable that these sandstones were the source of the polished siliceous grains characteristic of the Sylamore sandstone, and if this be a correct inference, a reason is apparent for the distribution of the Sylamore sandstone over surfaces which had not eroded so far down as this rock; since the place of sedimentation would not be the same with the place of erosion from which the materials were derived.

Further south, in the northeast corner of Washington County, Arkansas, specimens have been obtained containing a few ndistinct fossils which are important in interpreting the age of this interval-deposit.

No. 1279. War Eagle Creek, Washington County, 18 N., 28 W., section 15.

The materials were collected by Mr. Weller, and the section is described as a bed of black shale (1279A1) with very little iron pyrites, containing fossils, followed immediately by a reddish-gray limestone (1279A2) containing crinoid stems, but no distinct fossils. On the opposite bank, the black shale was found to be about 30 feet thick, but no fossils were discovered in it. The underlying rock was not seen. According to the map and descriptions given by Professor Simonds,* this is the Eureka shale underlying the Boone chert and limestone. The fossils are in imperfect, frail and crushed condition, but have a decidedly Carboniferous aspect. They also appear to belong to the

* Ark. Geol. Survey, Ann. Rept., 1888, vol. IV, Washington County. By F. W. Simonds.

same fauna, discovered in the greenish shale (1410M2) into which the black shale of Eureka Springs gradually merges before reaching the limestone above.

Three small collections from Newton County (1291 A, B and C) indicate the same fauna in greenish shale, and the several, together, present unmistakable evidence of the Chouteau fauna of the regions further north in Missouri.

No. 1291. Buffalo Fork, Newton County.

The materials from this region were collected by Mr. G. H. Ashley, and the localities are defined as follows, viz.:

1291A. Eureka shale, from N. W. quarter to S. W. quarter, 17 N., 21 W.

1291B. At base of St. Joe marble, probably; four miles south of Jasper, in Henson creek, one mile above mouth of Panther Creek, 15 N., 22 W., section 1, the southeast of the northwest quarter.

1291C. In shale on top of Sacchardoidal sandstone, 16 N., 22 W., section 9.

THE FAUNA OF THE INTERVAL-FILLING MATERIAL.

Although the fossils obtained from the black shales, the greenish shales following them and the nodules contained in the black shales, are very rare, imperfect and frail, a care study of the material has brought out features more or less distinct, by which their biological relations can be determined. The whole of this list may require some specific revision whenever better specimens come to light. Enough is preserved to make the generic identifications fairly certain. In determining them, great pains was taken to discover, if possible, signs of those particular characters which mark the difference between

closely allied species of successive known geological horizons. A few remarks may be given regarding the points thus ascertained concerning the more important genera.

Lingula. In the black shale strata, and in the black nodules of the greenish shales and Sylamore sandstone, a number of minute Lingula were seen. These were compared with a large series of specimens from the typical Genessee shales of New York, Cleveland, Bedford, Berea, Ohio, Huron, Portage, Ithica black shales, Harpeth shales of Tennessee, and from similar black-shale rocks of Europe. The conclusion from the study is that the forms common in the Genessee black shales of New York are the central and typical forms. These are often found almost alone. The most frequent associates are Conodont teeth and a small Chonetes. From these common black-shale forms the succeeding Lingulas differ by slight and indefiite gradation, until they reach a size five times as great as the typical Genessee types, and vary in dimensions and in thickness of shell.

The change, which is apparent in the New York sections, when the succession is distinct and clear, is from the very minute forms in the pure Genessee shale, to larger, broader and more rounded forms in the same shales; the variation in the Genessee specimens reaches a doubling or tripling of the typical sizes, and with modification in the general form. In the blackish shales higher up at about the Ithaca horizon, and in Portage strata when they are prevalent, and still higher in bands of shale coming in in the midst of Chemung strata, in western New York, the larger, broader, more rounded forms are seen. In the black shales in the Ohio sections, representing the upper part of the Chemung, and reaching up into undoubted Carboniferous horizons, the same form is traced, increasing somewhat with the rise in horizon and as they mix with other species. Finally, we reach a form, which is repre-

sented fairly well by Meek and Worthen's *Lingula subspatulata*. The fact that the subspatulata size and form are reached in the prevalent Tennessee type has led me to think that where it occurs the horizon is well up in the series rather than in a Mesodevonian horizon.

In the Arkansas case, the forms seem to me to come in near the upper limit of the Devonian, as expressed in the New York-Ohio region, on the supposition that the modification from the minute forms to the broader, oval, flat, enlarged forms of the Carboniferous horizons is one due to gradual evolution. But I do not feel perfectly confident that this is the case. I think it more likely that the conditions of environment at the same time would find expression in something of this modification. That the species is peculiar to the kind of sediments which, in their purity, constitute the black shale is quite evident from a wide study of their occurrences.

Cyrtina. In the brownish-black shale of station 1278 A1, several specimens, which I refer to *Cyrtina acutirostris* Shumard, are found. Several of the specimens are much crushed, but the high beak, the attenuated upper part, and broad and rather extended mesial sinus and few lateral plications, which are not so broadly rounded as in the figure, are the characters suggesting the species. The characteristic punctuations are not evident.

Spirifer. Several species of this genus are recognized. The specimens from 1291C (Y200) are clearly *S. marionensis*. Those from 1279A1 (Y423) are crushed and only fragments, but what is evident agrees with the similar parts of perfect specimens of *S. marionensis*. This species is frequently seen in the higher beds and across the line in Missouri; it is characteristic of the corresponding shales at the base of the Carboniferous. *S. biplicatus*, Hall is suggested by some crushed specimens (Y171), but the material is too imperfect for certain identification. *S. win-*

chelli, Herrick, cf. *S. mesacostalis*, a very perfect specimen (Y199) resembles very closely some specimens of the smaller variety of *S. mesacostalis* from the Ithaca group (Devonian) of New York. It is the type described by Herrick, from the Waverly of Ohio, under the name *S. winchelli*. Mr. Herrick suggests the close resemblance to *S. mesacostalis*, but in a note to the writer he says that Professor Winchell considered it to be undoubtedly a distinct species.

S. ? compactus, Meek. Some crushed specimens (Y172) from the green shales at Eureka Springs (1410M2) may belong to this species. It has the form of *pinguis*, or *suborbicularis*, Hall, and yet is too crushed to well make out the true proportions.

Spiriferina ? octoplicata. Specimens (Y173) fairly representing the character of this species, occur in the green shale at Eureka Springs (1410M2).

Athyris, is represented in the green shales (1291) by specimens, which are referred to *A. hannibalensis*, Swallow (Y201). Another specimen is referred with doubt to *A. fultonèsis*, Swallow, from the green shales of Eureka Springs (1410M2).

Chonetes. Two, and perhaps three, species of Chonetes occur in these shales:

C. illinoisensis. A single specimen of this species occurs in the soft green shale (1410M2), above the black, at Eureka Springs. It is smaller and more delicate than the typical forms of the species, but has the broad, flat, finely striated characteristics of *C. illinoisensis*. With it are associated many smaller forms, which may be of two or one species; the larger number are about the size and shape of the New York, *C. scitula*, but varying to the shape of *Koninckiana*. There are other specimens with fewer plications, which approach the character of Shumard's *Cornata*. It is altogether probable that the specimens described as *C. ornata*, Shumard, are the same species with

these. There is considerable range of variation among the specimens before me, and it seems not impossible that they all may represent a very variable species; since the larger forms are more finely striated by bifurcation of striae, and are flat and frail, as in the largest form which I have referred to *C. illinoisensis*. For purposes of references, until a fuller study of the genus is made, they may stand as *C. illinoisensis, ornata* and *? scitula*.

Productus. One fragmentary specimen from the green shales (1291) (Y204), though too imperfect to specifically identify, is distinctly a Carboniferous type, resembling *P. burlingtonensis*, Hall.

Productus hallanus, Walcott, is represented by several specimens from the green shale at Eureka Springs (1410M2), and from the Black shales at War Eagle Creek (1279A1).

The genus *Rhynchonella* is represented, but the crushed specimens make specific identification little better than guess-work. Their resemblance to similar crushed specimens, in the Tennessee greenish shales in the same geological position, and in the Waverly of Michigan and Ohio, which are generally referred to the species *R. sageriana,* Winchell, leads me to so label them. These frail, crushed Rhynchonellas are from the Eureka green shales (1410), and from the black shales at War Eagle Creek (1279). *R. acuminata var.*, is also seen in the green shales in Newton County (1291).

Orthidae. Of this family, several genera are represented. *Rhipidomella* (Oehlert), is represented by forms which are generally catalogued under the name *Orthis michelini*, L'Eveille; but, though crushed, the specimens before me are decidedly broader than that species, and thus are more like the Devonian types of *O. Vanuxemi* or *penelope*. In outline, they are close to that of *O. Oweni,* Hall (Pal. N. Y., vol. VIII, Brachiopoda I, p. 342, Fig. 19 of

Plate VI), but have no trace of the broad fold and sinus of that species. They are evidently the same species figured on Plate VI A of the New York Volume VIII, Bracìopoda I, and called *Orthis sp. ?* (*compare O. penelope*), from the Waverly group of Granville, Ohio.

As a name, I think it is probable that Hall first distinguished the species in question, in the Iowa Report of 1858 (Geol. of Iowa, Vol. I, Part 2), under the name *Orthis michelina, var. burlingtonensis,* so that they should be called *Rhipidomella burlingtonensis,* Hall. The specimens correspond more nearly to specimens in like condition in the Burlington than to the typical *O. vanuxemi* or *penelope,* though in some features recalling the latter. Another species, *Rhipidomella thiemii,* White, is a small species, and may prove to be but a young or small form of the *burlingtonensis* species, but, as it is frequently seen of the diminished size, it is safe to refer to it as a distinct species.

Schizophoria, is represented by a couple of faint impressions in the black shale of 1279A1 (Y489). This, of purpose of indentification, may be referred to *S. Swallovi,* Hall, with a query; sufficient evidence is present to refer it to this genus, but the crushed condition of the specimen makes it impossible to tell what its original form was.

Strophomenidae. Among the Strophomenidae, a few distinct representatives of the *Leptaena rhomboidalis* have been seen in the green shale of 1291.

Terebratuloid shells are difficult to identify, even when perfect, from the exterior alone, but a crushed fragment in the green shale of 1279A1 suggests strongly the form *Dieslasma.*

Burlingtonensis. We may refer to this as a possible species of the fauna.

In addition to the specimens whose generic affinities may be distinguished, there are *Conodont teeth*, fragments of *fish bones* which must have belonged to large mailed fish and *Crinoid stems.*

When the whole fauna is critically examined, though the specimens are nearly all in very imperfect, distorted condition, enough may be made out of their zoological affinities to settle the question of general horizon. The black shale, when it stands out distinct with a limestone below and above, presents a fauna which would link the horizon with that of the Genessee black shale of New York. But when we examine it where followed gradually by a green shale, becoming finally calcareous, and running up into thin, shaly limestone beds with the green shale alternating with it, before the pure limestone enters the section, the evidence of precise horizon is less positive. In such a case the fact, that the Genessee black shale has a definite geological horizon in the New York section, must not be allowed to limit the range of the fauna it contains. The fauna which is well exhibited as soon as the green shales are in force, is always of Carboniferous type; and in one case, we have a black shale also containing the same fauna, which I refer to the black shale of the War Eagle Creek section (1279A1), thus clearly indicating the stratigraphical continuity of the green and black shales of the general region.

The fauna associated generally with the pure black shale sediments in Arkansas, and in other regions in the south, is restricted to very few species, of which the Lingula is the most frequent often associated with Conodont teeth. This is also characteristic of the Genessee black shale of New York. My conclusion from the study of the whole problem is, however, that the fauna of the Genessee black shale, which has a definite limited position in the New York section, is a fauna of wide geological range, and is characteristic of the black shale conditions of sedimentation rather than of the particular limited horizon represented by the Genessee formation. The fauna in these fine shales in Arkansas, terminating and following the

black shales, is unmistakably much higher than the Genessee black shale of New York. Faunally, it is the correlative of the Louisiana or lithographic limestone, and is thus as late as the Kinderhook stage of the Eocarboniferous.

There can be no doubt regarding the Carboniferous age of the faunas of the typical Louisiana limestone. Its fauna is characteristically Kinderhook, Waverly, Chouteau, and it is not paleontologically correct to refer the Louisiana and Hannibal (or those Arkansas formations which belong to the same epoch) to the Devonian (as Mr. Keyes has done in the Biennial Report of the State Geologist of Missouri for 1897, page 59). The fauna of the shales terminating the interval deposits in Arkansas, is evidently the same as that seen in a similar position in the Louisiana section in Missouri, and thus belongs to the base of the Chouteau or Kinderhook group.

The age of the Sylamore sandstone and associated deposits.

From a study of all the evidence visible, both stratigraphical and paleontological, I have reached the following conclusions regarding the probable age of the formation of this interval-material. The distinct fossiliferous deposit of black shale seen in Cagen Creek section (1246A) cannot be distinguished paleontologically from the "Black shales" of the Tennessee, Kentucky and Indiana sections. The St. Joe sections indicate distinctly that the green shale and the Sylamore sandstone were formed at the same geological time, i. e. consecutively; and that the Carboniferous deposit, following, was formed after the Sylamore sandstone was laid down, hence that the sandstone with its nodules, and the green, mud-shale associated with it, are not later residual products of decay of the lower limestones, as Mr. Penrose explains the origin of the manganese-bearing interval material in Independence County. Again, the black nodules contain Lingulas as do the black shales; and the structure of the nodules, and the evident

agglutination of some of them, and the concretionary nature of the oölitic grains of which others are composed, all point to a concretionary mode of formation rather than to a simple rounding of broken fragments; while the extreme polishing and medium size with absence of finer grains of the sandstone, point to excessive erosion. Again, the fauna appearing next above this interval-material is in all cases, when covered by rock, of Carboniferous age; the species indicating generally a Chouteau fauna, in some cases later Chouteau with traces of Burlington, or Keokuk species.

The interpretation of these facts is that the typical interval-materials, the green shale and the Sylamore sandstone, were deposited after the period of the formation of the typical black shales which, along the borders of the Ozark uplift, was terminated, or actually driven outward, by the elevation of the region; that these particular deposits mark the stage of sinking again of the land and the resultant erosion which introduced the Carboniferous formations for this region; that the time was at the very close of the Devonian and beginning of the Carboniferous eras. I conclude that the explanation of the varying age and nature of these deposits is due to the sections having been taken at places at lower or higher position on the gradually sinking land, and expressing the overlap of the successively more recent deposits. This point, however, can be satisfactorily determined only by examination of the stratigraphical relations of the various formations. My judgment is based upon the relations of the various formations in the few sections presenting several of the formations in succession.

The descriptions in Dr. Penrose's Report (An. Rept., Ark. Geolog. Surv., 1890, Vol. I) of the stratigraphy of Independence County led me to infer a similar explanation of the facts there; but evidence was not then at hand to disprove the reference of the red limestones, lying above

the interval-accumulations, to the Silurian limestone. If Dr. Penrose was correct in his reference of the upper limestone, in the section of the O'Flynn mine (p. 231, Fig. 14), to the St. Clair limestone, it is difficult to discover any relationship between the Sylamore sandstone and the manganese deposit, which would be included in the midst of that limestone. Among the specimens sent in by Mr. Hopkins, there is no evidence of the Silurian limestone at the O'Flynn mine, but there does appear evidence of a deposit similar to the Sylamore sandstone in connection with the so-called manganese bed. The relationship exsting between the Sylamore sandstone, which is the phosphate-bearing rock of this region, and the manganese deposits described in the Batesville region, is not yet clear.

As Dr. Branner has suggested in a later discussion of the subject,* it would appear that the Sylamore sandstone, and the manganese deposits, are confused in some of the sections. Whether the reason for this is the wearing down of the Silurian series, so that the Devonian interval deposits were laid upon the surface of the manganese deposits (the Cason shale), or whether they have been let down by the solution of an originally intervening limestone, it is difficult to determine with the evidence now before us. There seems to be good evidence to suppose that they are not of the same geological age. Further study of the whole problem of the deposits filling the Devonian interval in the south† has led to the conclusion that, however much erosion of the underlying Silurian formation took place, the sediments of black mud forming the shale, did not begin till after the beginning of the Devonian era. The association of the fragments of thick bones of large fish with

* See the Phosphate Deposits of Arkansas, by J. C. Branner. Am. Inst. Min. Eng., 1896.

† See the southern Devonian.

the worn Sylamore sandstone, is observed on the eastern margin of the Cincinnati plateau in Kentucky. So far as our knowledge of the range of species goes, these fish were not living till the early part of the Devonian era. The black shale following such worn material suggests a sinking of the particular region, and when the shale and the worn fragments and nodules alternate, as they appear to do in central Tennessee, it may be taken as evidence of the continuous, shallow condition of the region, which was at that time the southern extension of the Cincinnati plateau.

NOTE.—While preparing this report for publication, I have seen Vol. III, Part II of the Minnesota Report,* and notice a remark which suggests the extension of this peculiar interval deposit as far north as Minnesota. Describing the section of the rocks at Prosser's ravine near Wykoff, Fillmore County, the authors state that "Succeeding the foregoing bed (which was of uncertain age, of 6 feet thickness, regarded as Upper Silurian, the passage of which lithologically from the Richmond group, upper Cincinnati group, is described as exceedingly gradual) and followed with not very strong evidence of unconformity by Devonian strata, is a sandstone four feet thick, which here and there contains large numbers of small quartz pebbles, varying between one and ten millimeters in diameter. This sandstone we assume to belong to the Oriskany of New York." (p. cv.) The evidence of elevation and erosion, prior to the deposit of this so-called Oriskany, is found in the absence of the formations immediately preceding the Devonian formation in complete sections. The beginning of permanent sedimentation with well-worn pebbles is what should be expected, as the land was depressed, whatever the time at which it took place. A similar thin

* Geology of Minnesota, vol. III, part II, of the final report. Paleontology, 1897, p. cv.

layer of much worn pebbles and sand, separates the magnesian limestones (Ordovician) from the underlying gneiss, at a section on the southern slopes of the Adirondack at Little Falls, New York. It is followed by black mud shale with Lingulas, and then the regular magnesian limestone of considerable thickness. So other cases might be cited, the age of the beginning of the new sedimentation being determined by the first fossils above the abrupt change, and the unconformity may not be indicated by conspicuous modification of the plane of sedimentation. We should less expect real unconformity in the central part of a continental mass, as in the Mississippi valley region, than on the borders where the folding and faulting has been chiefly concentrated.

THE CARBONIFEROUS FORMATIONS.

The terranes of Carboniferous age include the typcal Eureka shale, the St. Joe marble, the Carrollton limestone and the Cherty beds sometimes called Boone chert: (Boone chert and limestone being used as a single designation for all between the Eureka shale and Fayetteville shale, in Branner's paper of 1896*), the Spring Creek black shale and limestones, the Batesville sandstone and the Genevieve or Boston group.

The first fauna occurring above the Devonian interval (including deposits called Sylamore sandstone, Eureka shale and green shale) is of Carboniferous age in every section where fossils have been seen to tell the story. Nowhere have I seen evidence of any older formation succeeding this peculiar deposit, and sections have been examined all along the way from Independence County westward to Eureka Springs. The sections in the east show no marble following the interval, as at Long Creek (1414). Dodd City

* The Phosphate Deposits of Arkansas, Am. Inst. Min. Eng., Sept., 1896. See also An. Report, 1890, vol. IV, p. 96

(1282), and St. Joe (1238); further west the base of the Carboniferous terrane is more shaly, and greenish or grayish in color, as at Elixir Springs (1322), Marble City (1276), Eureka Springs (1410), and in the extreme northwestern part of the State at Sulphur Springs (1330).

In the more western sections the fact that the underlying shale is impervious to the water, explains the frequent occurrences of large springs issuing from the base of the Carboniferous limestone. Only a few fossils have been collected from the red marble, but in all cases they are Carboniferous species. *Spirifer grimesi,* Hall, occurs at St. Joe (1238), with Platycrinus plates and large Crinoid segments. In the Dodd City section (1238A3) a Rhynchonella, presenting the character of *R. cooperensis,* Shumard, and a small Productus, species undertermined was found. From the greenish more shaly deposits and gray limestones, such forms as:

Ceptaena rhomboidalis, Schizophoria and *Orthis Swalovi* appear at Elixir Springs.

Spirifer, cf. subcardiformis, Schizophoria swallovi, and *Rhipidomella suborbicularis* occur at Marble City (1276A2). The same fauna is seen in a similar shale at Elixir Springs (1332R3). Above these reddish and gray shales and shaly limestones appear the purer limestones with a richer fauna; but this lower part, particularly in the western part of the state, holds a fauna of decidedly Chouteau affinities, which become more marked as the corner of the Ozark uplift is rounded, and southwestern Missouri is studied. Here the typical Chouteau species and character of sedimentation begin.

In northern Arkansas, although some of the species are evidently characteristic Chouteau, the species quoted are, some of them Burlington and some Keokuk forms; but this admixture does not show that the species cited may not be characteristic of the separate horizons in the more

northern sections. In Arkansas and in some parts of Missouri, the species are not so separated, stratigraphically, as to call for a distinction of the formations.

The blending of faunas is rather to be expected in cases where, as with most of the types here mentioned, there are series of very closely related forms in the successive beds running from the base of the Carboniferous to the Coal Measures. If the succession of species was by natural generation with mutation, such admixtures would naturally take place unless every species of a fauna took upon itself to make its mutation at the same time.

CARBONIFEROUS LOCALITIES IN NORTHERN ARKANSAS.

At the following stations fossils have been gathered, indicating faunas of Carboniferous age.

1234—Batesville.

A. Ramsey's Ferry.

1235—Polk Bayou, Independence County.

A. On Polk Bayou, at small spring 2 miles above Batesville.

1236—Mountain View, Stone County.

A. Blue Mountain, south of town.

R. Marshall road, about 2 to 3 miles west of Lich Fork.

1237—Independence County.

R. 13 N., 7 W., section 13, the northwest of the southeast quarter.

S. 13 N., 7 W., section 21, the northwest of the northeast quarter.

1238—St. Joe, Searcy County.

A. Section along creek from mining camp to town.

B. Tomahawk creek, 5 miles east of St. Joe.

C. One mile southeast of 1238 B.

R. (White River) 1½ miles west of Buffalo Fork of White River, loose.
S. About 600 feet north of Morrison's mill, St. Joe.
T. St. Joe, Searcy County.

1246. Cagen Creek, Stone County, 3 miles north of Buck Horn.
A. Section in hollow, on south side of creek.
B. Section in hollow, 200 yards east of A.
C. Section up the creek, ½ mile above A and B, east side of creek.
R. Buck Horn, Stone County, 14 N., 9 W., section 3, John Greenway.
S. Buck Horn. (?) Near R.

1247. Marshall, Searcy County.
A. Sandstone quarry, ½ mile east of Marshall.

1248. Spring Creek, Independence County.
A. In R. R. cut, east of trestle, over wagon road.
B. Section in R. R. cut, just west of trestle.
C. In hollow, the mouth of which is at Chert bluff by R. R. trestle, next west to the one under which the wagon road runs to Spring Creek.
R. Spring Creek, Independence County.
S. "Batesville Sandstone" from road beyond Spring Creek.
T. Loose on R. R. embankment.
V. Loose on R. R. embankment.
W. Loose on R. R. embankment.
X. From Sandstone along R. R., just east of 1248A.
Y. R. R. embankment—loose.
Z. Loose on R. R. embankment.

1275. Valley Springs, Boone County.
A. Pilot Mountain, 3½ miles southwest of Valley Springs.

1276. Marble City, Newton County.
A. Section from creek, up the hill.

B. On Flat Rock Creek, 2 miles southeast of Marble City.

1278. Rush Creek, (?) Marion County.

A. Section along creek, opposite the mines.

B. At the Narrows on the hill, 3 miles from the mouth of Rush Creek.

1279. War Eagle Creek.

A. On War Eagle Creek in 18 N., 28 W., section 15.

1283. Batavia, Boone County.

A. On Harrison and Eureka Road, ¾ mile east of Batavia.

1284. Hindsville, Madison County.

A. On south side of Round Mountain.

1291. Henson Creek, Newton County.

A. 17 N., 21 W., section 27, the northwest of the northwest quarter.

B. 15 N., 22 W., section 1, the southeast of the northwest quarter, 4 miles south of Jasper, Henson Creek, one mile above mouth of Panther Creek, probably at base of St. Joe marble.

C. 16 N., 22 W., section 9, the northwest of the southwest quarter. In shale on top of Saccharoidal sandstone.

1322. Elixir Springs, Boone County.

A. Top of highest hills, Mill Run, near Reave's saw mill.

B. Elixir Springs, Boone County.

C. Loose denudation boulders, top of highest hills, supposed to be Grand Falls or Cherokee formations of W. P. Jenney.

D. Sugar Loaf Creek.

R. On hillside, north of town.

X. Loose pieces.

1330. Sulphur Springs, Benton County.
- A. Hills, ½ mile southeast of Sulphur Springs.
- B. Quarry in Chouteau limestone, northwest part of town.
- C. Quarry in northeast part of town.
- D. Head-waters of Honey Creek, 5 miles southwest Sulphur Springs.

1333. Eureka Springs, Carroll County.
- A. Hills, 1½ mile southwest of Crescent Hotel.

1410. Eureka Springs, Carroll County.
- A. Excavation for Bank building in city.
- M. Section at Dairy Spring.
- N. Swain Mountain on Huntsville and Eureka Springs road, south of Eureka Springs.

1411. Green Forest, Carroll County.
- A. A special fauna in Batesville sandstone, in quarried sandstone, lying near brook west of hotel.

1413. Carrollton, Carroll County.
- A. East side Long Creek.
- B. Cherts along road between Carrollton and Eureka Springs.
- C. Along road to Eureka Springs, above sandstone (Batesville).
- D. Beyond Carrollton, chert cliffs on Long Creek.
- M. At bluff along the creek, just south of the town.
- X. On Harrison Road, 2 miles west of Carrollton.

EOCARBONIFEROUS FAUNAS.

Faunas of the Eureka Shale.—The Eureka shale was seen at several localities, but only in the following sections were fossils discovered in such condition as to clearly indicate both the species and the relation of the deposits to earlier and later formations.

1410M. Dairy Spring, Eureka Springs, Carroll County.

The section at the Dairy Spring is as follows:

M5.	Hard bluish or reddish limestone.	?
M4.	Blue shaly limestone, parts of it becoming hard like M3, while other parts are almost like M2, no fossils seen.	5 feet.
M3.	Hard reddish limestone in horizontal layers about a foot thick, no fossils seen.	6 feet.
M2.	Soft blue shale, decomposing rapidly, many particles of pyrites, many small fossils.	1 foot.
M1.	Black shale, much iron pyrites, no fossils seen.	3 feet.

At 1410A, an excavation in the town of Eureka Springs, made for the foundation of a bank building, the same sequence was seen; viz. black shales, becoming green at top, followed by the Carboniferous limestone, but after careful search no fossils were detected in the shales.

The following species are from the green shale of 1410M2:

1. *Spirifer biplicatus* Hall.
2. *Spirifer cf. compactus Meek* (kinderhookensis, n. sp. Stuart Weller MSS.).
3. *Spiriferina cf. octoplicata* Sowerby.
4. *Chonetes cf. scitulus* Hall.
5. *Chonctes cf. ornatus* Shumard.
6. *Chonetcs illinoisensis* Worthen.
7. *Productclla hallana* Walcott.
8. *Athyris fultonensis* Swallow.
9. *Rhynchonella cf. plcurodon* Phillips, var.
10. *Orthis* (?) sp. (?)

1279A—War Eagle Creek, Washington County.

Section.

A2.	Reddish gray limestone, no fossils except Crinoid stems.	15 feet.

A1. Black shale with very little iron pyrites, numerous fossils. 4 feet.

Along the opposite bank of War Eagle Creek, the black shale is exposed about 30 feet thick. Here it contains much iron pyrites, but no fossils.

Fauna from black shale 1279A1.

1. *Chonetes cf. scitulus* Hall.
2. *Chonetes cf. ornatus* Shumard.
3. *Rhipidomella thiemei* White.
4. *Rhipidomella vanuxemi* Hall.
5. *Schizophoria cf. resupinata* Martin, var.
6. *Spiriferina cf. solidirostris* White.
7. *Spirifer marionensis* Shumard.
8. *Productella cf. hallana* Walcott.
9. *Cyrtina acutirostris* Shumard.
10. *Cf. Dielasma burlingtonensis* White.
11. *Rhynchonella cf. pleurodon* Phillips, var.

1246A—Cagen Creek, Stone County.

The section is in the hollow on south side of the creek.

A 3. Red marble.

A 2. Black shale, many specimens of small lingulas.

A 1. Pink Silurian limestone.

The only species found in A2 is:

1. *Barroisella subspatulata* (Meek and Worthen). (See p. —.)

1291. In Newton County the Eureka shales were met at three places. At station 1291C, (16 N., 22 W., section 9), the northeast of the southwest quarter, in a shale on top of the Saccharoidal sandstone, the following species were collected:

Fauna from 1291C.

1. *Spirifer marionensis* Shumard.
2. *Delthyris cf. mesacostalis* Hall.

3. *Cf. Pugnax acuminatus* Martin.
4. *Athyris hannibalensis* Swallow.
5. *Rhipidomella vanuxemi* Hall.
6. *Leptaena rhomboidalis* Wilckens.
7. *Productus* sp. (?)

These faunas are all from the shales immediately underlying the red Kinderhook limestone. It is greenish in some cases, but in War Eagle Creek it is a typical black shale and there constitutes the upper part of the sedimentation, though the Eureka shale is rarely fossiliferous when a pure black shale. The fossils leave no doubt as to the Kinderhook age of these faunas; and as in the several cases here given, the shale lies immediately upon the Silurian formations, there can be little doubt that this sediment was deposited after an erosion interval, beginning at the very terminal part of the Devonian era, or, as seems to me more probable from the character of these fossils, after the opening of the Carboniferous era.

The frequent appearance of springs of considerable magnitude in the northern part of the state at the base of the Carboniferous calcareous formations, and whenever the black shale is present at its upper surface,* suggests the probability that the interval deposits have been more or less removed or disintegrated when they were soluble. The frequent appareance of iron pyrites in the upper part of the shales accounts for the acidulated waters needed to make the solution of the calcareous part of the sediments.

Such erosions of the rocks will explain some of the irregularity of the sections from the black shale up to the red marble. But below the black shale is the great unconformity, which I have accounted for by elevation and absence of sedimentation. This constitutes what I have

* Arkansas Geological Survey, Ann. Rept., 1890, vol. IV, pp. 345-346.

called the Devonian interval; the first sedimentation of this interval is represented by the Sylamore sandstone and the base of the black shales.

Faunas of the St. Joe Marble.—The red or pink limestone lying at the base of many of the Carboniferous sections, seen typically at St. Joe, Searcy County, is called in the reports St. Joe Marble. This contains a typical Kinderhook fauna. It is exposed in the following localities:

1322R, 1248C, 1330B and C, 1291A, B, C, 1283A, 1278B.

1322R. Elixir Springs, Boone County.

Section.

R3. Hard gray limestone, corresponds to the red marble, and is in places red, but most of it is like the Lithographic limestone of Missouri.

R2. Saccharoidal sandstone.

R1. Magnesian limestone exposed along foot of hill.

Fauna from 1322R3.

1. *Leptaena rhomboidalis* Wilckens.
2. *Rhipidomella vanuxemi* Hall.

1238C. St. Joe, Searcy County.

Section.

C7. Higher part of red marble.

C6. Red marble.

C5. Slamore sandstone.

C4. Green shale.

C3. Polk Bayou limestone.

C2. Blue marble, above Calciferous.

C1. Magnesian layer in Calciferous.

Fauna from 1238C7.

1. *Spirifer grimesi* Hall.
2. *Zaphrentis* sp. (?)
3. Crinoid columns.

1330B. Sulphur Springs, Benton County.

Section, — Quarry in Chouteau limestone, north-west part of town.

Fauna from **1340 B2.**

1. *Spirifer marionensis* Shumard.
2. *Spirifer* (*kinderhookensis*, n. sp. Weller MSS.) *cf. compactus* Meek.
3. *Spirifer striatiformis* Meek.
4. *Spirifer cf. mesacostalis* Hall.
5. *Leptaena rhomboidalis* Wilckens.
6. *Athyris hannbalensis* Swallow.
7. *Athyris prouti* Swallow.
8. *Rhipidomella vanuxemi* Hall.
9. *Productella hallana* Walcott.
10. *Rhynchonella cooperensis* Shumard.
11. *Cf. Dielasma burlingtonensis* White.
12. *Cf. Zaphrentis tenella* Miller.
13. *Cf. scaphiocrinus missouriensis* Shumard.

1330C. Sulphur Springs, Benton County.

Section.

C2. Burlington limestone quarry. (W. P. Jenney.)

C1. Chouteau limestone quarry. (W. P. Jenney.)

Fauna from 1330C2.

1. *Spirifer marionensis* Shumard.
2. *Spirifer* (*kinderhookensis*, n. sp. Weller MSS.) cf. *compactus* Meek.
3. *Spirifer striatiformis* Meek.
4. *Pugnax acuminatus* Martin.
5. *Ptychospira sexplicata* White and Whitfield.
6. *Athyris hannibalensis* Swallow.
7. *Athyris prouti* Swallow.
8. *Athyris* (?) sp. (?)
9. *Spiriferina octoplicata* Sowerby.

10. *Productella hallana* Walcott.
11. *Rhipidomella thiemei* White.
12. Cf. *Chonetes ornatus* Shumard.
13. Cf. *Zaphrentis tenella* Miller.
14. Caplus sp. (?)
15. Bryozoa.
16. Crinoid columns.

1282A. Dodd City, Marion County.

Section.

A3. Red marble, contact not seen.

B2. White sandstone (? Sylamore sandstone),

A1. White saccharoidal sandstone.

Fauna from 1282A3.

1. *Productella hallana* Walcott. (?)
2. *Rhynchonella cooperensis* Shumard.

1278B. Rush Creek, Marion County.

Section.

B3. Red marble, fossils.

B2. White sandstone (? Sylamore sandstone), with numerous black water-worn pebbles. 4 in.

B1. Very hard, heavy bedded blue limestone, no fossils.

Fauna from 1278B3.

1. *Spirifer* (*kinderhookensis*, n. sp. Weller MSS.)
2. Cf. *Spirifer marionensis* Shumard.
3. *Athyris hannibalensis* Swallow.
4. *Schizophoria resupinata* Martin, var.
5. *Rhipidomella vanuxemi* Hall.

1276A. Marble City, Newton County.

Section.

A2. Red marble numerous gray parts, many fossils. 60 feet.

A1. Silurian sandstone, no fossils.

Fauna from 1276A2.

1. *Schizophoria swallovi* Hall.
2. *Rhipidomella michelini* (L'Eveille).
3. *Spirifer ovalis* Phillips (? young).

1276B. Marble City, Newton County.
Section.
B1. Ledge of white limestone, probably belonging to the red (St. Joe) marble formation about 30 feet above the contact of Silurian and Carboniferous, fine fossils.

Fauna from 1276B.

1. *Spirifer grimesi* Hall.
2. *Athyris lamellosa* L'Eveille.
3. *Cleiothyris roissyi* L'Eveille.
4. *Athyris prouti,* Swallow. (?)
5. *Rhipidomella michelini* L'Eveille.
6. *Capulus equilaterus* Hall.

THE CARROLLTON LIMESTONE.

There is a cliff of gray limestone in the ravine at Carrollton, Carroll County, Arkansas, whose fauna is evidently more recent than that of the Red Marbles of other parts of the state. But the sections observed do not present the two formations in stratigraphic sequence. I have called the gray limestone, Carrollton limestone; its fauna is well represented in the limestone marked 1412M and A, 1339D, 1283A1, 1276B. The faunas, from the lists following, will be seen to present a combination of species which are distributed commonly into the two separate faunas of the Burlington or Keokuk formations. It was this combination of species, making it impossible to distinguish the horizon as Keokuk or Burlington (and there are also forms which usually characterize the Warsaw formation) which led me, in the study of these formations, to use the name

Osage as a term indicating the lack of differentiation of these faunas in this southern area. The name first applied, and proposed to Mr. Winslow, then State Geologist of Missouri, and also to Dr. Branner, was Ozark which seemed an appropriate one for this important paleontologic division of the Mississippian faunas. As will be explained beyond, the adoption of the name Osage was for the purpose of gratifying Professor Broadhead, who wished to use the name Ozark in another sense.

Faunas of the Carrollton limestone.

1413M. Carrollton, Carroll County.

Section.

M2. Red or yellow sandstone.

H1. Blue-gray limestone, parts dense, other parts soft and porous, much chert, many fossils. 50 feet

Fauna from 1413M1.

1. *Reticularia pseudolineata* (Hall).
2. *Spirifer tenuicostatus* Hall.
3. *Spirifer keokuk* Hall.
4. *Cf. productus punctatus* Martin.
5. *Productus marginicinctus* Prout.
6. *Productus cora* D'Orbigny.
7. *Camarophoria isoryncha* McCoy.
8. *Derbya keokuk* Hall.
9. *Chonetes illinoisensis* Worthen.
10. *Rhipidomella dubia* Hall.
11. *Spiriferina octoplicata* Sowerby.
13. *Athyris lamellosa* L'Eveille.
14. *Dielasma formosa* Hall.
15. *Rhynchonella pleurodon* Phillips, var.
16. *Syringothyris textus* Hall.

17. *Phillipsia* (*Griffithides*) *bufo* Meek and Worthen.
18. *Zaphrentis centralis* Edwards and Haime.

1413A. Carrollton, Carroll County.

Section.

A. Limestone ledges east side Long creek.

Fauna from 1413A.

1. *Spirifer logani* Hall.
2. *Spirifer keokuk* Hall.
3. *Retecularia pseudolineata* Hall.
4. *Spirifer ovalis* Phillips.
5. *Dielasma formosa* Hall.
6. *Phillipsia* (*Griffithides*) *bufo* Meek and Worthen.
7. *Platyceras* sp. (?)

1339D. Eidson's Still House, 9 miles northeast of Fayetteville.

(Section not given.)

Fauna from 1339D.

1. *Syringothyris textus* Hall.
2. *Derbya keokuk* Hall.
3. *Murchisonia keokuk* Worthen.
4. *Chonetes illinoisensis* Worthen.
5. *Productus punctatus* Martin.
6. *Productus cora* D'Orbigny.
7. *Productus* n. sp. (*Eurekensis* Weller MSS.) Y236.
8. *Productus mesialis* Hall.
9. *Rhynchopora* n. sp. (=*R. osagensis* Weller MSS.) Y230.
10. *Spirifer rostellatus* Hall.
11. *Reticularia pseudolineata* Hall.
12. *Spirifer ovalis* Phillips.

13. *Spiriferina octoplicata* Sowerby.
14. *Cleiothyris roissyi* L'Eveille.
15. *Capulus equilaterus* Hall.
16. *Orthonychia acutirostre* Hall.
17. *Zaphrentis versoviensis* Worthen.
18. *Zaphrentis centralis* Edwards and Haime.
19. *Amplexus fragilis* White and St. John.
20. *Phillipsia* (*Griffithides*) *portlocki* Meek and Worthen.
21. *Conocardium* sp. (?)
22. *Fenestella* (?) sp. (?)
23. Fish remains.

1283A. Batavia, Boone County.

Section.

A2. Yellow or brown sandstone exposed on top of hill up the road.

A1. Gray limestone exposed in small quarry on north side of road, many fossils, cherty limestone.

Fauna from 1283A1.

1. *Productus punctatus* Martin.
2. *Productus burlingtonensis* Hall.
3. *Spirifer logani* Hall.
4. *Derbya keokuk* Hall.
5. *Spiriferina octoplicata* Sowerby.

THE BOONE CHERT.

Faunas of the Boone Chert.—The fossils of the Boone chert were not obtained in place, but from loose blocks, at stations 1333 and 1330. They represent about the same fauna as that of the Carrollton limestone, but are silicified. The petrographic difference between the St. Joe marble and the Boone chert does not, so far as I am aware, indi-

cate any uniform stratigraphic relationship, but the cherty conditions are apparently local.

1333A. *Fauna from loose specimens of Boone chert, in the region of Eureka Springs.*

1. *Spirifer logani* Hall.
2. *Spirifer tenuicostatus* Hall.
3. *Spirifer rostellatus* Hall.
4. *Spirifer keokuk* Hall.
5. *Spirifer ovalis* Phillips.
6. *Reticularia pseudolineata* Hall.
7. *Spirifer kelloggii* Swallow.
8. *Spirifer neglectus* Hall.
9. *Spiriferina octoplicata* Sowerby.
10. *Cyrtina neogenes* Hall.
11. *Productus setigerus* Hall.
12. *Productus mesialis* Hall.
13. *Productus punctatus* Martin.
14. *Productus* n. sp. (=*P. eurekensis* Weller MSS.) Y342.
15. *Productus cora* D'Orbigny.
16. *Productus marginicinctus* Prout.
17. *Chonetes illinoisensis* Worthen.
18. *Chonetes planumbonus* Meek and Worthen.
19. *Derbya keokuk* Hall.
20. *Athyris lamellosa* L'Eveille.
21. *Cleiothyris roissyi* L'Eveille.
22. *Cleiothyris hirsuta* (Hall).
23. *Camarospira* n. sp. (=*C. trinuclea,* Weller MSS.) Y344.
24. *Dielasma formosa* Hall.
25. *Camarophoria subcumeata* Hall.
26. *Camarophoria isoryncha* McCoy.
27. *Rhynchopora* (?) n. sp. (=? *R. osagensis* Weller MSS.) Y317.

28. *Rhipidomella michelini* L'Eveille.
29. *Eumetria Marcyi* (Shumard).
30. *Hustedia mormoni* Marcou.
31. *Capulus equilaterus* Hall.
32. *Igoceras pabulocrinus* Owen.
33. *Capulus* sp. (?)
34. *Eccyliomphalus* (?) n. sp. (=*E. osagensis* Weller MSS.) Y320.
35. *Amplexus fragilis* White and St. John.
36. *Zaphrentis centralis* Edwards and Haime.
37. *Zaphrentis varsoviensis* Worthen.
38. *Aulopora gracilis* Keyes.
39. *Phillipsia* (*Griffithides*) *bufo* Meek and Worthen.
40. *Macrocrinus verneuilanus* (Shumard).
41. *Schizoblastus granulosus* Meek and Worthen.
42. *Cypricardina scitula* Herrick.
43. *Aviculopecten oblongus* Meek and Worthen.
44. *Aviculopecten* sp. (?)

1330E. *Fauna from loose specimens of Boone chert, in the region of Sulphur Springs, Benton County.*

1. *Spirifer logani* Hall.
2. *Spirifer tenuicostatus* Hall.
3. *Spirifer ovalis* Phillips.
4. *Reticularia pseudolineata* Hall.
5. *Spirifer rostellatus* Hall.
6. *Spiriferina octoplicata* Sowerby.
7. *Cyrtina neogenes* Hall.
8. *Productus marginicinctus* Prout.
9. *Productus* n. sp. (=*P. eurekensis* Weller MSS.) Y368.
10. *Productus cora* D'Orbigny.
11. *Chonetes illinoisensis* Worthen.
12. *Derbya keokuk* Hall.

13. *Dielasma formosa* Hall.
14. *Rhynchopara* n. sp. (=*R. osagensis* Weller MSS.) Y360.
15. *Schizophoria swallovi* Hall.
16. *Rhipidomella dubia* Hall.
17. *Cleiothyris roissyi* L'Eveille.
18. *Eumetria marcyi* Shumard.
19. *Phillipsia* (*Griffithides*) *bufo* Meek and Worthen.
20. *Amplexus fragilis* White and St. John.
21. *Zaphrentis centralis* Edwards and Haime.
22. *Platycrinus* sp. (?)
23. *Cypricardina scitula* Herrick.
24. Lamellibranch.
25. Gasteropod.

1330A. *Fauna from loose specimens of chert, Hills, ½ mile southeast of Sulphur Springs, Benton County.*

1. *Schizoblastus sayi* Shumard.
2. *Pentremites elongatus* Shumard.
3. Cf. *Pentremitidea americana* Barris.
4. Cf. *Eremocrinus calyculoides* Hall.
5. *Platycrinus* (several species).
6. *Orophocrinus* (?) sp. (?)
7. *Poteriocrinus* sp. (?)
8. Cf. *Synbathocrinus wortheni* Hall.
9. *Athyris proutii* swallow.
10. Cf. *Athyris lamellosa* L'Eveille.
11. *Athyris* sp. (?)
12. *Spirifer grimesi* Hall.
13. *Spirifer ovalis* Phillips.
14. *Spirifer imbrex* Hall.
15. *Spiriferina octoplicata* Sowerby.
16. *Syringothyris* sp. (?)
17. *Chonetes illinoisensis* Worthen.

18. *Productus setigerus* Hall.
19. *Dielasma formosa* Hall.
20. *Capulus equilaterus* Hall.
21. *Zaphrentis centralis* Edwards and Haime.

Faunas of the Spring Creek limestone.

Under this name are classified the faunas of the following stations:

1248A. Spring Creek, Independence County.
1236A3. Mountain View, Stone County.
138B. St. Joe, Searcy County.
1413T. Carrollton, Carroll County.

The typical locality is Spring Creek, Independence County, a few miles west of Batesville, near the railway.

THE SPRING CREEK LIMESTONE.

In the Annual Report for 1890,* a black limestone is described, under the name Fayetteville shale, which presents certain paleontological features so important that I have classified it under a distinct name, viz., the Spring Creek limestone.†

The Fayetteville shale was originally described in the report for 1888, and from Washington County. There it is described as "almost if not completely barren of fossils." Its stratigraphical position is between the Boone chert and the Archimedes limestone of that report.‡

In the Batesville region, Independence County, the exposures are along a line of faults; such a fault runs through the locality at Spring Creek and confuses the stra-

* Arkansas Geol. Survey, Ann. Rept., 1890, vol. I, Manganese, Penrose, p. 138; also see sections, pp. 111 and 113.

† On the Recurrence of Devonian Fossils in strata of Carboniferous age. Am. Jour. Sci., 3d Ed., vol. 49, p. 94, 1895.

‡ Geol. Survey of Ark., Ann. Rept. for 1888, vol. IV, p. 42.

See also the Batesville sandstone of Arkansas, by Stuart Weller, Trans. N. Y. Acad. Sci., vol. XVI, p. 279, 1897.

tigraphy. Drs. Branner, Penrose and I examined the locality in 1889 and 1890; and in the following year Mr. Stuart Weller made a careful examination of the stratigraphy, noted the fossiliferous zones and added to the collections of fossils.

The principal section is in the railroad cut east of the trestle over the wagon road, of which the following description was prepared by Mr. Weller:

1248A. Section.

A13. A fine-grained grit runs down into A12 in several places and is decomposed. (This may be the upper termination of the limestone where it underlies the Batesville sandstone which is said by Dr. Penrose to overlie the Fayetteville shale.*)

A12. Black limestone, generally solid, heavy bedded, in some places quite shaly, varies greatly. The lower three inches contain fossils, and also fossils occur higher up in bands and pockets. 8 feet

A11.	Brown shale, few fossils,	3 inches
A10.	Black limestone, hard, no fossils,	2 feet
A9.	Brown shale, no fossils,	4 inches
A8.	Black limestone, hard, no fossils,	6 inches
A7.	Black shale, becoming brown at top no fossils,	10 inches
A6.	Black limestone, hard, fossils abundant, weathers like A5,	18 inches
A5.	Brown gritty shale, many fossils,	6 inches
A4.	Soft yellow shale, almost decomposed to clay, no fossils,	6 inches to 2 feet
A3.	Black limestone, hard, no fossils,	12 to 18 inch.
A2.	Brown gritty shale, many fossils,	6 inches
A1.	Black shaly limestone, many fossils.	

* Ann Rept., Ark. Geol. Surv., 1890, vol. I, p. 139.

THE FAUNA.

Although there is considerable difference between the calcareous and non-calcareous beds, the whole terrane of some 20 feet is faunally tied together by the presence of the Leiorhynchus in the strata A1, A2, A5, A6, and A11.

In weathering the arenaceous character of the beds appears. In the more calcareous beds the fossils are preserved with their original convexity; but in the shales they are more or less flattened and crushed, and all seem to have been quite thin and delicate. A notice of some of the remarkable features of the fauna was given in 1894.*

In the several beds of 1248A the following species were seen:

Fauna of 1248A (1-12), *the Spring Creek limestone.*

1.	*Rhynchonella eurekensis* Walcott.	Y114
2.	*R. cf. pleurodon* Phillips.	Y115
3.	*Leiorhynchus quadricostatum papyraceum* (Meek).	Y112
4.	*Dielasma turgida* (Shumard).	Y128
5.	*Eumetria marcyi* (Shumard).	Y131
6.	*Seminula argentea* (Shepard).	Y124
7.	Cf. *Cleiothyris roissyi* L'Eveille.	Y124a
8.	*Ambocoelia planoconvexa* (Shumard).	Y129
9.	*Martinia glabra contracta* (Meek and Worthen).	Y130
10.	*Spirifer bisulcatus* Sowerby.	Y125
11.	*Spirifer keokuk* Hall.	Y127
12.	Sp. ? sp.	Y126
13.	*Productella* cf. *lachrymosa* Hall and variations).	Y116

* On the recurrence of Devonian fossils in strata of Carboniferous age. (Read before Geol. Soc. Am., Dec., 1894.) Am. Jour. Sci., vol. XLIX, Feb., 1895, pp. 94-101.

14.	*Productella* cf. *hirsutiforme* Walcott.	Y118
15.	*Productus cestriensis* Worthen.	Y123
16.	*Productus cora* D'Orbigny var.	Y121
17.	*Productus semireticulatus* Martin var.	Y119
18.	*Productus* cf. *biseriatus* (small).	Y120
19.	*Productus* ? sp.	Y122
20.	*Lingula* cf. *mytiloides* Sowerby.	Y132
21.	*Lingula* ? sp.	Y132a
22.	*Discina* ? sp.	Y132
23.	Several minute Brachiopods (undetermined).	
24.	*Nucula rectangula* McChesney.	Y139
25.	*Nuculana vaseyana* (McChesney).	Y140
26.	*Macrodon* cf. *tenuistriatus* M. & W.	Y141
27.	*Aviculopecten* cf. *catactus* Meek.	Y142
28.	Cf. *Sanguinolites* sp.	
29.	Cf. *Allorisma* sp.	
30.	Cf. *Euomphalus* sp.	
31.	*Platystoma* sp.	Y167
32.	? *Platystoma* sp. (minute).	Y135
33.	Cf. *Platyceras* sp.	Y137
34.	*Bellerophon sublaevis* Hall.	Y134
35.	*Goniatites* (minute).	
36.	*Bactrites* (minute).	
37.	? *Paleoniscus* and other fish scales and teeth.	Y143
38.	*Fenestella*, trace.	
39.	Crinoid segments.	

This, from a purely paleontological point of view, is one of the most interesting, as well as perplexing, faunas coming from these Arkansas rocks. The geologists who have studied the ground identify the formation with the Fayetteville shale of Washington County, and place it immediately under the Batesville sandstone. Dr. Penrose describes a fault cutting through the strata at the chief

locality where the fossils were obtained, which further complicates the interpretation of the fauna. From careful study of the outcrop by several observers, there can no longer be doubt that the species cited occur together in the same continuous series of conformable strata.

The most conspicuous and common fossils are a *Leiorhynchus*, a *Rhynchonella*, one or two species of *Lingula*, a large *Spirifer*, a *Productella* and a Productus. The *Leiorhynchus*, as it appears in the limestone, is gibbous and quite unlike, in general appearance, any of the New York *Rhynchonellas*, defined under that name by Hall. But among the specimens are crushed examples, reduced to condition of casts by trituration, which are well represented by Hall's figures of *Licorhynchus mesocostalis*;* others are fairly represented by figures 26 and 27 of the same plate, called *L. globuliformis*. The general form of the *L. Kelloggi* is nearer that of the Arkansas specimens when in limestone, but the form described by Meek from Nevada as "*Leiorhynchus quadricostatus* Vanuxem ? sp." accurately represents the characteristics of specimens from Arkansas.† This type of *Ryhnchonella* has heretofore been regarded as exclusively Devonian. Much interest attaches to it and the associated faunas because of the evident relationship between the Arkansas and Nevada faunas, and also because of the uncertain evidence of the fossils as to precise age. From the reference made by Mr. Meek (p. 80) to King's article in the American Journal of Science,‡ where the name "*Leiorhynchus quadricostatus* Hall=*Rhyn.* (*Leiorhynchus*) *papyraceous* Meek," is given it seems probable that the latter specific name is the

* Pal. New York, vol. IV, plate 57, figures 22, 23

† U. S. Geological Exploration of the 40th Parallel, vol. IV, p. 79, Plate III, figures 9, 9a and 9b.

‡ Clarence King, on the Paleozoic subdivisions on the 40th Parallel, American Journal of Science, vol. CXI, pp. 475-482, June, 1876.

one used by Meek in manuscript for the species under consideration. The figures of Meek, and the description, indicate his species to have been extremely close to the specimens in hand from Arkansas, which are, as above described, more like the New York *Rhy.* (*L.*) *mesocostalis*, or *globuliformis* than the ordinary form of *L. quadricostatus*. If a specific name were to be given, Meek's name *papyraceus* certainly should be adopted. However, these points of nomenclature may be discussed more appropriately when the fauna shall be figured and described.

In addition to the "*Rhynchonella* (*L.*) *quadricostatus* Vanuxem ? (sp.)" of Meek's report, in the Arkansas shales occur also an *Aviculopecten*, which bears very close resemblance to *A. catactus*, presenting the form of Meek's figure 10b, and the plications as figured on 10a, and as described on page 93 of the same report. Both of these species are reported from the unique fauna of White Pine District, from a black, bituminous shale, associated with some more or less arenaceous beds, beneath well-marked Carboniferous beds. (See p. 9 of same report.) The same fauna is further referred to in the same volume, in the chapter containing Hall and Whitfield's Paleontology, Pt. II, pp. 197, etc. On pages 200 and 201 reference is made to the fauna of the black slates, near Eberhardt Mills, White Pine Mountains, Nevada, with what is supposed to be an unmistakable Devonian fauna. It is stated (p. 201) that immediately above them are black, slaty layers bearing Carboniferous fossils. The whole description of the confusion is almost perfectly duplicated in the case of the black shales and limestones at Spring Creek, Arkansas. No additional light is thrown on the problem, and the authors rest with calling the lower black shale "Devonian," and layer above—"black shale of Coal Measure age."

In Walcott's report on the Paleontology of Eureka District, we find more species suggestive of the Arkansas

fauna. They are *Rhynchonella Eurekensis* Walcott,* which is from "the lower portion of the Carboniferous group" in the Eureka District, Nevada; and *Rhynchonella (L.) Nevadensis* Walcott,† which closely resembles the more convex forms of the Leiorhynchus from Arkansas, and is from the "Devonian limestone, Rescue Hill, Eureka District, Nevada." A Rhynchonella referred to Hall's species *Leiorhynchus sinuatus* is reported from the "upper horizon of the Devonian limestone" of the same district. The finely plicated *Rhynchonella Eurekensis* Walcott, is quite unique among American Paleozoic forms; and the coincidence of so many species occurring together in similar strata, in such widely separated regions, and not elsewhere so far as known n the country, is of much importance in solving the relations of the Arkansas fauna.

Associated with them are Producti, which are more nearly like the Upper Devonian Productellas of New York Chemung than any other known American forms. Specimens among them, as to spines and form, closely resemble *P. lachrymosa* of New York, with some of the hirsute characters of *onusta,* or *hirsuta;* others possess fine striations as in *costata.* The general Devonian aspect is evident. One of the Productellas closely resembles Walcott's *hirsutiforme* from the White Pine shale of Nevada.‡

Productus cora and P. semireticulatus are both represented; but the more common form is identified with *P. cestriensis* which is also abundant in the Batesville sandstone. This latter species serves both to tie together the Batesville sandstone and Spring Creek limestone, and to prove the Genevieve, not Osage, age of the faunas.

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* U. S. Geol. Survey Monograph, vol. VIII, p. 223, plate XVIII, figures 8, 8a, 8b, 8c.

† P. 157, plate XIV, figure 9.

‡ Paleontology of Eureka District, p. 133, pl. II, figs. 10, 10a.

In the case of one of the abundant Spirifers (abundant in the pure, lighter colored limestones, but not abundant in the arenaceous or black layers in which the other species are found) there is a feature of uncertainty. The species is, for American species, intermediate between *Spirifer arenosus* of the Lower Devonian, and *Spirifer grimesi* of the Burlington. It appears to be a new species for America. The interruption of the race, represented by *S. arenosus* and *unicus,* till the Upper Devonian at least (more accurately, till the Lower formations of the Carboniferous) suggests the possibility of such a form continuing on under special conditions into the Carboniferous. Some of the specimens, however, present the character of *Spirifer bisulcatus* Sowerby, and provisionally I have referred it to that species.

As has already been announced, the age of the Spring Creek limestone is about equivalent to the Warsaw, St. Louis or Spergen Hill formations.* Mr. Weller has confirmed this opinion by an exhaustive study of the closely related Batesville sandstone fauna which follows it.† In his paper he makes the Spring Creek limestone to be equivalent to the St. Louis limestone, and the Batesville sandstone to the Aux Vases sandstone. The study of the fauna makes clear that it expresses the departure of the old fauna of the Boone chert and associated limestone, and the introduction of a new fauna. Such species as *Dielasma turgida*, *Eumetria marcyi*, *Productus cestriensis*, *P. cora* and *P. biserialis,* as well as the absence of the characteristics of the Osage fauna, distinguish the income of the third, dominant Carboniferous fauna.

This definite order in the sequence of a few dominant faunas in the Mississippian rocks was first forced upon

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* Am. Jour. Sci., III, vol. XLIX, pp. 94-97, Feb., 1895.

† Trans. N. Y. Acad. Sci., vol. XVI, p. 281, July, 1897.

my attention by the attempt to accurately correlate the Arkansas and more southern Missouri faunas with the typical Iowa and Mississippi valley faunas described by Hall. Later study has confirmed the opinion, first communicated to Dr. Branner by letter and incorporated in his report for 1890,* that this classification of the paleonological succession and grouping is in general correct. In that report I divided the Mississippian series, on a paleonological basis, into three groups—Chouteau, Osage and Genevieve.

I proposed the application of the name Chouteau to the first time-division, adopting Broadhead's name,† in order not to confuse it with the stratigraphical division, Kinderhook, which is a better name for the structure scale. In speaking of the formations, Kinderhook or Waverly have the precedence over Chouteau, and they may be substituted for Chouteau.

The term Osage was proposed to include all the formations containing the Burlington and Keokuk faunas. The name first communicated to Dr. Branner was Ozark, but this name was withdrawn before the publication of the report, and the name Osage was substituted to accommodate Mr. Broadhead, who wished to use Ozark for another purpose. This statement will explain, to those who have attempted to displace the name, why the really best name was not adopted.

The name Genevieve was applied to the rocks containing the St. Louis and Chester faunas, and part of those referred to the Warsaw. This name was proposed for the Archimedes group of Shumard, as explained in my Correlation paper, in order to preserve the classification which Dr. Shumard was the first to observe. The name of the

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* Ann. Rept. of Geol. Surv. Ark. for 1890, vol. I, pp. 112-116, 1891.

† Rept. Geol. Surv. of Missouri, 1873-74, pp. 20-24, Jefferson City, 1874.

county in which the classification was first applied to the group in question, was adopted.*

In the same month (Dec., 1889) in which the classification was communicated to Dr. Branner for the Arkansas Survey, I sent to Mr. Winslow, then State Geologist of Missouri, at his request, a report on the classification of the Missouri formations including an announcement of the same scheme.

In the following year, I prepared the first (to be published) of the Correlation papers of the U. S. Geol. Survey, and in it I announced more fully the reasons for recognizing the three-fold division of the Mississippian series on a paleontological basis, while continuing to recognize the accepted structure scale.†

As will be seen in my table (on p. 265 of that report) Chouteau was proposed as a name in the time-scale. Chouteau was stated to be synonymous with the structural, stage-name Kinderhook, which had been earlier proposed. Hence, until the structure and time-scales can be considered apart, Kinderhook, Chouteau and Waverly are terms practically synonymous, and it matters little which is used so long as the paleontological value of the division be recognized.

In the classification of the Arkansas rocks I, at first, considered the Batesville sandstone to belong to the Osage group as defined above.‡ More careful study convinced me that it was a later fauna and I announced the fact in 1895.§ Mr. Weller's admirable paper on this fauna has demonstrated this fact for the Batesville

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* Geol. Surv. of Missouri, 1885-1871, pp. 292-3, 1873.

† Bulletin U. S. Geol. Survey, No. 80, Devonian and Carboniferous, pp. 269 and 265.

‡ Ann. Rept. Geol. Surv. Ark. for 1890, p. 115, 1891.

§ Am. Jour. Sci., 3, vol XLIX, pp. 95-96, 1895.

sandstone.* The list of species of the Spring Creek limestone here reported is further proof that it, with the Batesville sandstone, should be classed in the Genevieve group.

The true age of the Fayetteville shale is, as yet, uncertain. If it be the true equivalent of the Spring Creek limestone, it too should be put into the group of formations holding the third Carboniferous fauna. The Spring Creek limestone here described is generally called Fayetteville shale in the Arkansas reports, and I know no evidence to contradict this interpretaton, but the typical Fayetteville shale of Washington County is reported as almost entirely barren, while the formation so called in Independence County holds a rich fauna as has been already shown.

It is of interest to note the connection between the sharp and decided change of fauna and the change in the lithology of the rocks. The passage, beginning with the red marble, is from argillaceous shales, through calcareous shales, limestones, pure and with abundant marine fossils, and often crystallized, to cherty limestone, becoming more and more cherty to the top. Then comes a sudden change; black shales, and black sheets of limestone, with siliceous sand mixed with them; sometimes beds of sandstone; but the order is various and different in separate sections a few miles apart.

It was in this black shale and limestone, with more or less sandstone, that the new fauna arrived, in the present case, a remarkable fauna for the locality. It includes species which have never been seen before in the Mississippi valley, but are known in Nevada. It includes species which were never before known to occur so late in the series, but are common types in the preceding Devonian. The fauna points to some change by which communication was made with distant localities in the, then, sea basin.

* Trans. N. Y. Acad. Sci., vol. XVI, pp. 254, 278, etc., 1897.

The lithology points to a change in level, i. e. in the relative position of the land and bottom surface and the surface of the ocean. A similar sequence is seen in the passage from the Lower Helderberg limestone into the Oriskany, in the south (Virginia and West Virginia), and a similar change took place in these faunas.

It perplexes one to imagine exactly what was the nature of the physical change. The sands, and associated iron, suggest the nearer presence of land where the sediments were found. The black shales with sparse, often minute, and often pelagic species, seem to indicate deep, and hence quiet bottom conditions. These latter conditions are also indicated by the very smooth, even sedimentation of the black shales.

But may not the effect have been produced by protection of shallow seas from wave motion, by vegetable growth, as of a sargasso sea, on their surface? However, the fact may be explained, it is to be noted that it is not an unfrequent fact for great biological change in the fossil contents to be associated with the passage from limestone into sandstones and black shales.

The three next following faunas (1236A, 1238B, 1413X) probably belong with the Spring Creek fauna. The mode of occurrence of the black limestones in those sections, the tratigraphic order of which is known, suggests a closer relationship between the faunas of the Spring Creek limestone and Batesville sandstone than is indicated by stating that the Batesville sandstone succeeds the Spring Creek limestone.

The "lenticular beds of gray, black or brown shale," reported by Penrose,* are evidences of the coincidence of the two kinds of sedimentation. I expect that it will be found, as the sections are more thoroughly studied that the

* Ann. Rept. Ark. Geol. Surv. for 1890, vol. I, 1891, p. 139.

income of the new fauna, after the period of the Boone cherts, is associated with standstone, sandy shales and black shales, with only occasional lenticules of limestone; thus binding into one general formation what are now called the Spring Creek limestone and the Batesville sandstone. Nevertheless, the faunas are quite distinct for the sandstone and the calcareous beds, when pure.

1236A. Mountain View, Stone County.

Section.

A3. Ledge of black limestone half way up the mountain. The rocks immediately below are covered with debris, limestone probably rests on the shale, many very fine fossils.

A2. Black shale along base of mountain.

A1. Yellow sandstone, no fossils.

Fauna from 1236A3.

1. *Productus mesialis* Hall.
2. *Productus cora* D'Orbigny.
3. *Chonetes illinoisensis* Worthen.
4. *Leiorhynchus quadricostatum papyraceum* Vanuxem.
5. *Rhynchonella eurekensis* Walcott.
6. Cf. *Grammysia minor* Walcott.
7. Cf. *Schizodus deparcus* Walcott.
8. *Aviculopecten* sp. (?)
9. *Capulus acutirostris* Hall.
10. *Michelinia* sp. (?)
11. *Fenestella* (?) sp. (?)

1238B. St. Joe, Searcy County.

Section.

B1. Ledge of black limestone, fine fossils.

Fauna from 1238B.

1. *Chonetes illinoisensis* Worthen.
2. *Productus mesialis* Hall.

3. *Productus cora* D'Orbigny.
4. *Hustedia mormoni* Marcou.
5. *Cleiothyris hirsuta* Hall.
6. *Seminula trinuclea* Hall.
7. *Dielasma formosa* Hall.
8. *Archimedes* sp (?)
9. *Fenestella* (?) several species.
10. Crinoid columns.

1413X. Carrollton, Carroll County.

Section.

X4. Black shale.

X3. ? Red or yellow sandstone.

X2. Thin bed of limestone, fossils.

X1. Red or yellow sandstone.

Fauna from 1413X.

1. *Cleiothyris hirsuta* Hall.
2. *Athyris* sp. (?)
3. Cf. *Dielasma bovidens* (Martin).
4. *Dielasma formosa* Hall.
5. *Eumetria marcyi* Shumard.
6. *Spirifer keokuk* Hall.
7. *Productus cestriensis* Worthen.
8. *Rhynchonella* (sp.) (?)
9. *Nucula shumardana* Hall.
10. *Nuculana nasuta* Hall.
11. *Aviculopecten talboti* Worthen.
12. Cf. *Cyclonema levenworthanum* Hall.
13. *Bellerophon sublaevis* Hall.
14. Cf. *Belerophon carbonarius* Cox.
15. *Straparollus similis* Meek and Worthen.
16. Cf. *Pleurotomaria nodulostriata* Hall.

THE BATESVILLE SANDSTONE.

The typical locality of the Batesville sandstone is the sandstone bluff at Ramsey's Ferry (1234A), Batesville, Independence County, which was exploited by Dr. Branner in 1889, who then sent in a few fossils for identfication; and in the following year I examined the locality and collected more fossils. I then regarded the fauna as indicating a position higher than the Burlington and Keokuk limestones, but did not recognize its relation to the third Carboniferous fauna till later.

The sandstone has been recognized in other localities; viz., 1248X, Spring Creek; 1411A, Green Forest; 1413M, Carrollton, and 1247, Marshall; but in none of these localities were the blocks containing the fossils found in place. They were either loose blocks, or isolated ledges, whose relation to other strata was not determined.

The stratigraphical position of the sandstone as made out by the geologists, is supported by the paleontological evidence of the fossil contents. After the geological position of the sandstone was satisfactorily determined, and had been defined in the annual reports, Mr. Stuart Weller made an exhaustive study of the fauna, using some of the material belonging to the U. S. Geological Survey and in my charge, but collecting other and more complete material for the Walker Museum of the University of Chicago, where are deposited the types of the newly described species of his report. His list is based chiefly on the collections made by himself.

In this paper,* thirty species are mentioned, as follows:

Polyzoa.
Orbiculoidea batesvillensis sp. nov.

* The Batesville Sandstone of Arkansas. By Stuart Weller. Trans. N. Y. Acad. Sci., vol. XVI, 251-282, plates XIX, XX and XXI, July 19, 1897.

Streptorhynchus williamsi sp. nov.
Productus cestriensis Worthen.
Rhynchonella mutata Hall (?)
Spirifer Keokuk Hall.
Spiriferina sp. (?)
Athyris subquadrata Hall.
Eumetria verneuilana Hall.
Dielasma turgida Hall, var. elongata var. nov.
Pinna arkansana sp. nov.
Pteronites hopkinsi sp. nov.
Pteronites laevis sp. nov.
Myalina arkansana sp. nov.
Lithophaga(?) *batesvillensis* sp. nov.
Aviculopecten batesvillensis sp. nov.
Aviculopecten(?) sp.
Allorisma walkeri sp. nov.
Allorisma arkansana sp. nov.
Schizodus batesvillensis sp. nov.
Schizodus depressus Worthen. (?)
Schizodus(?) sp.
Sanguinolites(?) sp. (?)
Capulus acutirostris Hall.
Bellerophon sublaevis Hall.
Belerophon branneri sp. nov.
Straparollus similis Meek and Worthen. (?)
Straparollus sp. (?)
Orthoceras eurekensis Walcott. (?)
Glyphioceras sphaericus Martin. (?)

Mr. Weller reached the following conclusions as to the age of the Batesville sandstone from his study of the excellent material in hand:

"After a careful investigation of both the paleontologic and the stratigraphic evidence, it is believed that the position of the Batesville sandstone is definitely established

as the equivalent of the Aux Vases sandstone of southern Illinois and southeastern Missouri.

"The paleontologic evidence also points to the equivalence of the Batesville sandstone and the Maxville limestone of Ohio, but in this case the evidence can not be strengthened by a comparison of the stratigraphy of the two regions involved."*

The following lists are combinations of species found at several localities in the State, and are believed to represent the Batesville sandstone faunas. They were obtained from stations marked as follows: 1248X, 1411A, 1413M, 1247A. The location of each is indicated in the heading of each of the lists which follow.

1248X. *Batesville sandstone fauna from loose material at Spring Creek near Batesville.*

1. *Productus cestriensis* Worthen.
2. *Spirifer keokuk* Hall.
3. *Eumetria marcyi* Shumard.
4. *Dielasma* sp. (?)
5. *Derbya keokuk* Hall, var.
6. *Camarotoechia pleurodon* Phillips, var.
7. *Schizodus depressus* Worthen (?)
8. *Schizodus chesterensis* Meek and Worthen.
9. *Aviculopecten monroensis* Worthen.
10. *Glyphioceras kentuckiense* Miller.
11. *Orthoceras eurekense* Walcott (?)
12. *Pleurotomaria* (?) sp. (?)
13. *Fenestella.*

1411A. *Batesville sandstone (?) fauna at Green Forest, Carroll County.*

1. *Modiola illinoisensis* Worthen.
2. *Myalina concentrica* Meek and Worthen.

* See Trans. N. Y. Acad. Sci., vol. XVI, p. 282.

3. *Allorisma maxvillense* Whitfield.
4. *Edmondia* (?) *carrollensis* n. sp.
5. *Sphenotus* sp. (?)
6. *Spirifer keokuk* Hall.
7. *Eumetria maryci* Shumard.
8. *Derbya keokuk* Hall, var.
9. *Bellerophon sublaevis* Hall.
10. *Orthoceras* sp. (?)
11. *Phillipsia* sp. (?)
12. *Fenestella* sp.

1413M. *Batesville sandstone fauna at Carrollton, Carroll County, Loose Material.*

1. *Productus cestriensis* Worthen.
2. *Spirifer keokuk* Hall.
3. *Derbya keokuk* Hall, var.
4. *Dielasma* sp. (?)
5. *Aviculopecten monroensis* Worthen.
6. *Aviculopecten indianensis* Meek and Worthen (?)

1247A. *Marshall, Searcy County.* (No section given.)

1. *Productus cora* D'Orbigny.
2. *Schizodus chesterensis* Meek and Worthen.
3. *Fenestella* (?) sp. (?)

THE BOSTON GROUP.

The faunas included in the following lists indicate Carboniferous age, probably later than the Spring Creek limestone and the Batesville sandstone, but the exact place of equivalency in the series cannot be established with certainty from examination of the fossil lists alone. A fuller study of the sections will be required, and a close comparison of the species with typical representatives of the species concerned, before exact correlation will be reached.

The lists are given in this place, therefore, as preliminary lists, of Carboniferous faunas which may be provisionally classed in Branner's "Boston Group," awaiting more minute classification.

1275A. Valley Springs, Boone County. The following section was observed:

A10.	Coarse limestone, many pebbles, much iron, some fossils,	5 feet
A9.	Sandstone and shale intermingled, shale micaceous in places,	50 feet
A8.	Brown limestone, many fossils, Archimedes,	30 feet
A7.	Coarse ferruginous sandstone with beds of shale,	115 feet
A6.	Coarse-grain gray limestone, many Archimedes,	15 feet
A5.	Brown sandstone, no fossils,	40 feet
A4.	Black shale, thickness unknown,	(?)
A3.	Debris covering possibly sandstone and shale,	240 feet
A2.	Black shale, many fossils, Lingula,	100 feet
A1.	Red or yellow sandstone, no fossils, chert limestone,	35 feet

Fauna from 1275A8 *and* 1275A10.

1. *Goniatites cyclolobus* Phillips.
2. *G. branneri* n. sp.
3. *Rhynchonella* n. sp.
4. *Athyris ambigua* Sowerby.
5. *Schizophoria resupinata* Martin, var.
6. *Productus cestriensis* Worthen (?)
7. *Productus*, sp. (?)
8. *Bellerophon sublaevis* Hall.
9. *Macroodon* (?) sp. (?)
10. *Aviculopecten* sp. (?)

11. *Entolium* (?) sp. (?)
12. *Chaetetes* sp. (?)

Only the two Goniatites occur in A10, and one of these, *G. clyclolobus,* also occurs in A8.

1292A2. *Fauna from Washington County.*

1. *Spirifer keokuk* Hall.
2. *Spirifer integricostus* Phillips.
3. *Athyris ambigua* Sowerby.
4. *Productus longispinus* Sowerby.
5. *Productus cestriensis* Worthen.
6. *Productus cora* D'Orbigny.
7. *Derbya keokuk* Hall, var.
8. *Agassizocrinus* sp. (?)

1292B2. *Lemons Coal Bank, Washington County.*

1. *Myalina swallovi* McChesney.
2. *Myalina angulata* Meek and Worthen (?)
3. *Schizodus arkansanus* n. sp.
4. *Avicula ohioense* Herrick (?)
5. *Aviculopecten* sp. (?)
6. *Yoldia stevensoni* Meek.
7. *Derbya keokuk* Hall, var.
8. *Eumetria marcyi* Shumard.
9. *Productus cora* D'Orbigny.
10. *Productus cestriensis* Worthen.
11. *Athyris ambigua* Sowerby (young?)
12. *Spiriferina octoplicata* Sowerby.
13. *Spirifer keokuk* Hall.
14. *Spirifer* sp. ?
15. *Orthoceras randolphense* Worthen.
16. *Orthoceras rushense* McChesney.' (?)
17. *Orthoceras* sp. (?)
18. *Leouroceras chesterensis* Meek and Worthen.
19. *Nautilus* sp. (?)

20. *Gastrioceras kingii* Hall and Whitfield. (?)
21. *Pleurotomaria turbiniformis* Meek and Worthen.
22. *Straparollus catilloides* Conrad (?)
23. *Phillipsia* sp. (?)
24. *Archimedes* sp. (?)
25. *Michelinia* sp. (?)

1284A1. *Fauna from Brown Sandstone,* ¾ mile southwest of Hindsville, Madison County. Fossils from a loose boulder.

1. *Myalina swallovi* McChesney.
2. *Myalina concentrica* Meek and Worthen.
3. *Aviculopecten* sp. (?)
4. *Pinna maxvillensis* Whitfield. (?)
5. *Capulus ovalus Stevens.* (?)
6. *Archimedes* sp. (?)
7. *Michelinia* sp. (?)
8. *Derbya keokuk* Hall, var.
9. *Camarophoria explanata* McChesney.
10. *Eumetria marcyi* Shumard.
11. *Spiriferina octoplicata* Sowerby.
12. *Spirifer keokuk* Hall.
13. *Productus cestriensis* Worthen. (?)

1339B. *Fauna from a thin local layer of dark limestone* in Fayetteville Shale, near Eidson's Still House, Washington County.

1. *Productus cestriensis* Worthen.
2. *Productus punctatus* Martin.
3. *Productus mesialis* Hall.
4. *Productus cora* D'Orbigny.
5. *Productus longispinus* Sowerby.
6. *Dielasma formosa* Hall, var.
7. *Athyris ambigua* Sowerby.

8. *Spirifer keokuk* Hall.
9. *S. integricostus* Phillips.
10. *Reticularia perplexa* McChesney.
11. *Eumetria marcyi* Shumard.
12. *Derbya keokuk* Hall, var.
13. *Chonetes illinoisensis* Worthen.
14. *Camarospira trinucles* n. sp.
15. *Camarotoechia pleurodon* Phillips, var.
16. *Orthoceras* sp. (?)
17. *Grammysia minor* Walcott (?)
18. *Aviculopecten* (?) *hertzeri* Meek.
19. *Griffithides sangamonensis* Meek and Worthen. (?)
20. *Zaphrentis* sp.

1330D. *Fauna from Headwaters of Honey Creek,* 5 miles southwest of Sulphur Springs, Benton County.

1. *Athyris ambigua* Sowerby.
2. *Camarotoechia pleurodon* Phillips, var.
3. *Productus cora* D'Orbigny.
4. *P. longispinus* Sowerby.
5. *Spirifer bentonensis* n. sp.
6. *S. lineatus* Hall (?)

1339C. *Fauna from limestone just above the chert conglomerate,* near Eidson's Still House, Washington County.

1. *Rhynchonella pleurodon* Phillips, var.
2. *Productus cestriensis* Worthen.
3. *P. longispinus* Sowerby.
4. *Reticularia perplexa* McChesney.
5. *Athyris ambigua* Sowerby.
6. *Eumetria marcyi* Shumard.
7. *Dielasma formosa* Hall, var.
8. *Derbya* sp. (?)

CHAPTER VIII.

BIBLIOGRAPHY OF THE GEOLOGY OF NORTH ARKANSAS.

The following list includes all the titles of books and pamphlets relating to the geology of the lead and zinc region of North Arkansas. Newspaper articles are not listed. Some of the articles mentioned treat principally of the geology of the adjoining regions of Indian Territory and Missouri, but they have been included in the list because they throw much light upon Arkansas geology. The region of these references is that lying north of the Boston Mountains and west of the St. Louis, Iron Mountain and Southern Railway.

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INDEX.

THE REPORTS OF THE GEOLOGICAL SURVEYS OF ARKANSAS.

The following list includes all of the official reports made and published by the several Geological Surveys carried on by the State of Arkansas.

In 1893 the Legislature provided that the Secretary of State should distribute one copy each of all volumes published after May, 1892, to "colleges and high schools of this State, and universities and scientific institutions of other States." He was also supplied with a limited number of all volumes by the Survey under J. C. Branner "for distribution to scientists and capitalists." It was provided, however, "that before the Secretary of State shall be authorized to distribute any of the reports to scientists or capitalists . . . he shall require the applicant to state in writing that he is a scientist or capitalist, and that he wishes the reports to aid him in investigating the mineral resources of the State." It was further specified "that the Secretary of State shall not be authorized to distribute any of the reports to scientists or capitalists until the postage or express charges on same have been paid." (Acts of Arkansas, 1893, pp. 226-7.)

For the reports printed under the act of 1899 (that is, the Report on Zinc and lead), it is provided that 200 copies should go to the state Librarian for exchange with other States and territories. "Of this number he shall also send to each of the colleges of the State, and shall upon request supply one copy each to State universities of other States, and to such institutions of learning, geological societies, academies of science, etc., as may apply for such copies, one copy each, to be distributed at the discretion of the Secretary of State, the total number of copies so distributed not to exceed two hundred." (Acts of Arkansas, 1899, p. 267.)

Any of the reports may be purchased at the prices mentioned in the list. With the exception of the reports by the Survey under D. D. Owen, which are bound in paper, and the Annual Report for 1887, which is a pamphlet, the volumes (8vo) are uniformly bound in black cloth.

Requests and orders should be addressed to the

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Little Rock, Arkansas.

LIST AND PRICES OF THE REPORTS.

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	Price.	Postage.
First Report of a Geological Reconnoissance of the Northern Counties of Arkansas, made in 1857-1858. Pp. 256	$5.00	.09
Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas made in 1859-1860. Pp. 431	3.00	.18

(*B.*) *By the Survey under W. F. Roberts, Sr., State Geologist.*

	Price.	Postage.
Report by George Haddock. Pp. 59. Little Rock. 1873	(Out of print)	

(*C.*) *By the Survey under J. C. Branner, State Geologist.*

	Price.	Postage.
Annual Report for 1887, by J. C. Branner—Administrative. Pp. 15	.10	.02

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Vol. I.—Gold and Silver, by Theo. B. Comstock. Pp. xxxi, 320; 2 maps	1.00	.12
Vol. II.—Mesozoic, by R. T. Hill. Pp. xiv, 319; illustrated; 1 map	1.00	.13
Vol. III.—Coal (preliminary), by Arthur Winslow. Pp. x, 120; illustrated; 1 map	.75	.08
Vol. IV.—Washington County, by F. W. Simonds; Plant List, by J. C. Branner and F. V. Coville. Pp. xiv, 262; illustrated; 1 map	1.00	.11
Annual Report for 1889.		
Vol. I.—Clays, Kaolins, and Bauxites. Illustrated; maps by J. C. Branner; about four hundred pages	(Not yet published)	
Vol. II.—Crowley's Ridge, by R. E. Call. Pp. xix, 283; illustrated; 2 maps	1.00	.13
Annual Report for 1890.		
Vol. I.—Manganese, by R. A. F. Penrose, Jr. Pp. xxvii, 642; illustrated; 3 maps	1.35	.26
Vol. II.—Igneous Rocks, by J. Francis Williams. Pp. xv, 457; illustrated; 6 maps	1.35	.13
Vol. III.—Novaculites, by L. S. Griswold. Pp. xx, 443; illustrated; 2 maps	1.25	.22
Vol. IV.—Marble, by T. C. Hopkins. Pp. xxiv., 443; illustrated; atlas of 6 maps	1.35	.25
Annual Report for 1891.		
Vol. I.—Mineral Waters, by J. C. Branner. Pp. viii, 144;; 1 map	1.00	.09
Vol. II.—Miscellaneous Reports—Benton County, by F. W. Simonds and T. C. Hopkins; Elevations, by J. C. Branner; River Observations, by J. C. Branner; Magnetic Observations, by J. C. Branner; Mollusca, by F. A. Sampson; Myriapoda, by Charles H. Bollman; Fishes, by Seth E. Meek; Dallas County, by C. E. Siebenthal; Bibliography of the Geology of Arkansas, by John C. Branner. Pp. x, 349; illustrated; 2 maps	1.25	.22
Annual Report for 1892.		
Vol. I.—Iron Deposits, by R. A. F. Penrose, Jr. Pp. x, 153; 1 map	1.00	.10
Vol. II.—Tertiary, by Gilbert D. Harris. Pp. xiv, 207 illustrated; 1 map	1.00	.13
Vol. III.—Coal, final report; illustrated; topographic maps and sections. By Arthur Winslow and others	(Not yet published)	
Vol. IV.—Lower Coal Measures; topographic maps, sections, and illustrations. By J. H. Means and George H. Ashley	(Not yet published)	
Vol. V.—The Zinc and Lead Region of North Arkansas by J. C. Branner. Pp. xiv, 375; atlas of seven maps; illustrated		